a28

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 9/28/77

Project Title: "Program for Solar Energy Meteorological Research and Training Site." (Region No. 3)

Project No: E-16-630 (Sub-accounts are: E-15-610; E-21-615; B-08-605; B-495; B-496)

Project Director: Dr. C. G. Justus

Sponsor: Energy Research and Development Administration

Agreement Period: From 9/30/77 Until 9/29/78 (Grant Period)

Type Agreement: Grant No. EG-77-G-05-5604

Amount: $144,623 (ERDA Funds-E-16-630)
32,667 (GIT Funds-E-16-318)
$177,290

Reports Required: Contract Mgmt. Summary Rpts, Technical Status Rpts., Technical Progress Rpts.

Sponsor Contact Person (s):

Technical Matters	Contractual Matters (thru OCA)
Michael R. Riches U. S. Energy Research and Development Administration Division of Solar Energy 20 Massachusetts Avenue Washington, D. C. 20545 (202) 376-4471	F. O. Christie, Director Contract Division, ORO U. S. Energy Research and Development Administration Oak Ridge Operations P. O. Box E Oak Ridge, TN 37830 (615) 483-8611

Defense Priority Rating: N/A

Assigned to: Aerospace Engineering (School/Laboratory)

COPIES TO:

Project Director	Library, Technical Reports Section
Division Chief (EES)	Office of Computing Services
School/Laboratory Director	Director, Physical Plant
Dean/Director—EES	EES Information Office ✓
Accounting Office	Project File (OCA)
Procurement Office	Project Code (GTRI)
Security Coordinator (OCA) ✓	Other
Reports Coordinator (OCA) ✓	

CA-3 (3/76)

Pos ~~ad~~ add OH

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 1/2/79

Project Title: Program for Solar Energy Meteorological Research and Training Site, (Region No. 3)

Project No: E-16-630/E-15-610/A-57-605/E-21-615

Project Director: Dr. C. G. Justus/Dr. J. R. Williams/Ms. J. M. Wood/Dr. J. H. Schlag

Sponsor: Department of Energy

Effective Termination Date: 9/29/78 (01 yr. only)

Clearance of Accounting Charges: 9/29/78 (continued as E-16-C01, E-15-C01, A-57-C01, E-21-C01)

Grant/Contract Closeout Actions Remaining:

- _ Final Invoice and Closing Documents
- x ~~Final~~ Fiscal Report (year 01)
- x ~~Final~~ Report of Inventions (interim)
- _ Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- _ Other ____________

Assigned to: AE/Eng. Col./VPR/EE (School/Laboratory)

COPIES TO:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director—EES
Accounting Office
Procurement Office
Security Coordinator (OCA) ✓
Reports Coordinator (OCA)

Library, Technical Reports Section
Office of Computing Services
Director, Physical Plant
EES Information Office
Project File (OCA)
Project Code (GTRI)
Other ____________

CA–4 (3/76)

FORM ERDA 536
(11/30/76)

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

CONTRACT MANAGEMENT SUMMARY REPORT

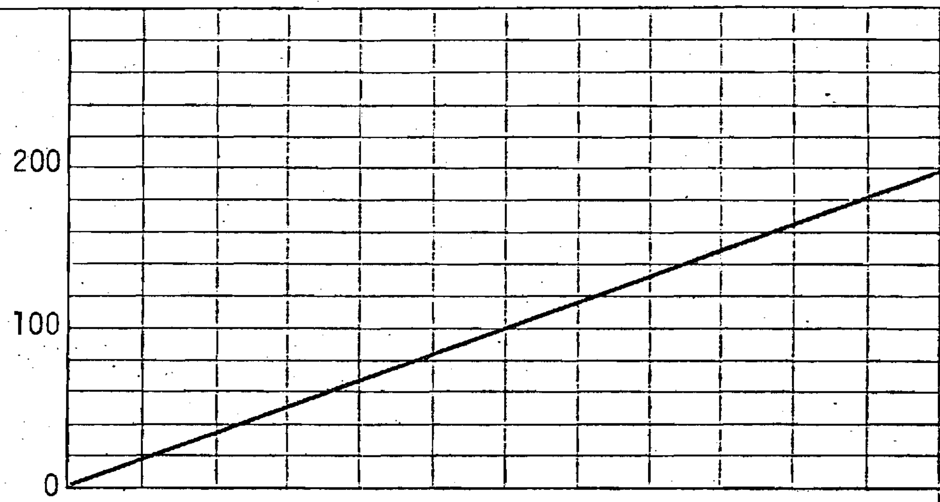
FORM APPROVED

1. Contract Identification Program for Solar Energy Meteorological Research and Training Site (Region 3)	2. Reporting Period Initial Projection	3. Contract Number EG-77-G-05-5604
4. Contractor (name and address) School of AE, Ga Tech Atlanta, GA 30332		5. Contract Start Date 9/30/77
		6. Contract Completion Date 9/29/78

7. Months	O	N	D	J	F	M	A	M	J	J	A	S	8. FY 78

9. Cost Status

a. Cumulative Costs $1,000



e. Actual Costs Prior FYs: 0

f. Planned Costs Prior FYs: 0

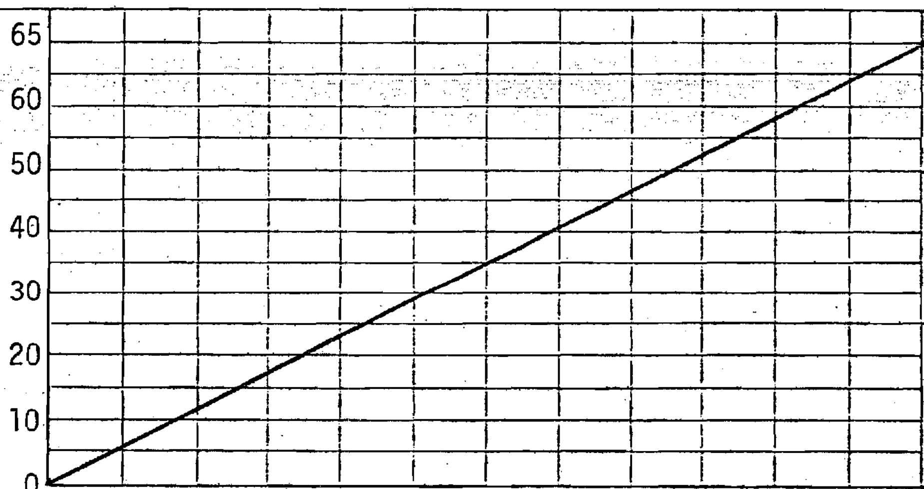
g. Total Projected Accrued Costs for Contract: $200,000

h. Total Contract Value: $200,000

Accrued Costs													
	b. Planned												
	c. Actual												
	d. Variance												

10. Manpower Status

a. Cumulative Man Months



e. Actual Manpower Prior FYs: 0

f. Planned Manpower Prior FYs: 0

g. Total Projected Manpower for Contract: 65 man months

h. Total Contract Manpower: 65 man months

Manpower													
	b. Planned												
	c. Actual												
	d. Variance												

11. Major Milestone Status

a. See attached Detail Milestone Chart

12. Remarks

13. Signature of Contractor's Project Manager and Date 10/10/77

14. Signature of Government Technical Representative and Date

Figure 2.1 - Schedule and Milestone Chart

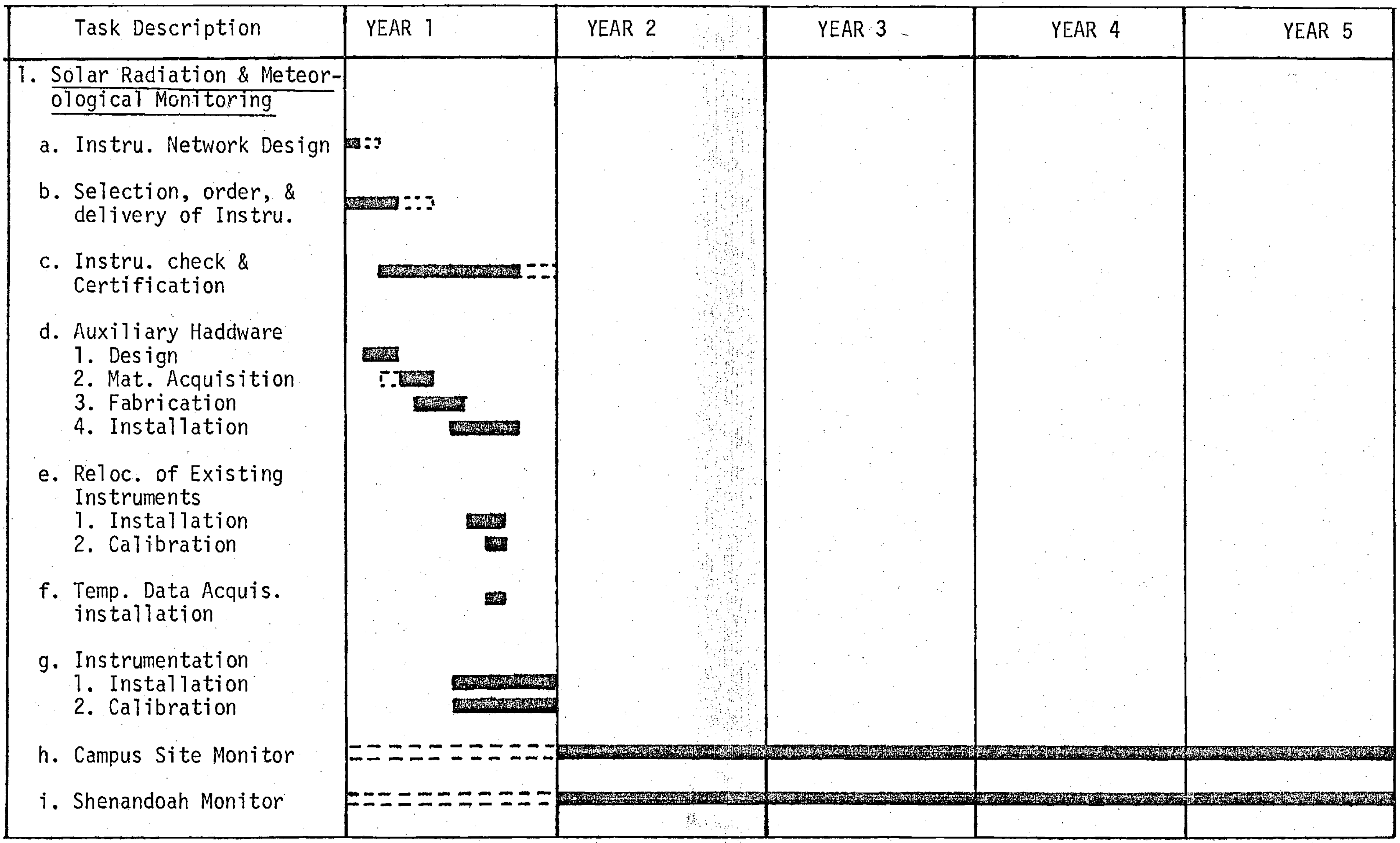


Figure 2.1 (Cont'd.)

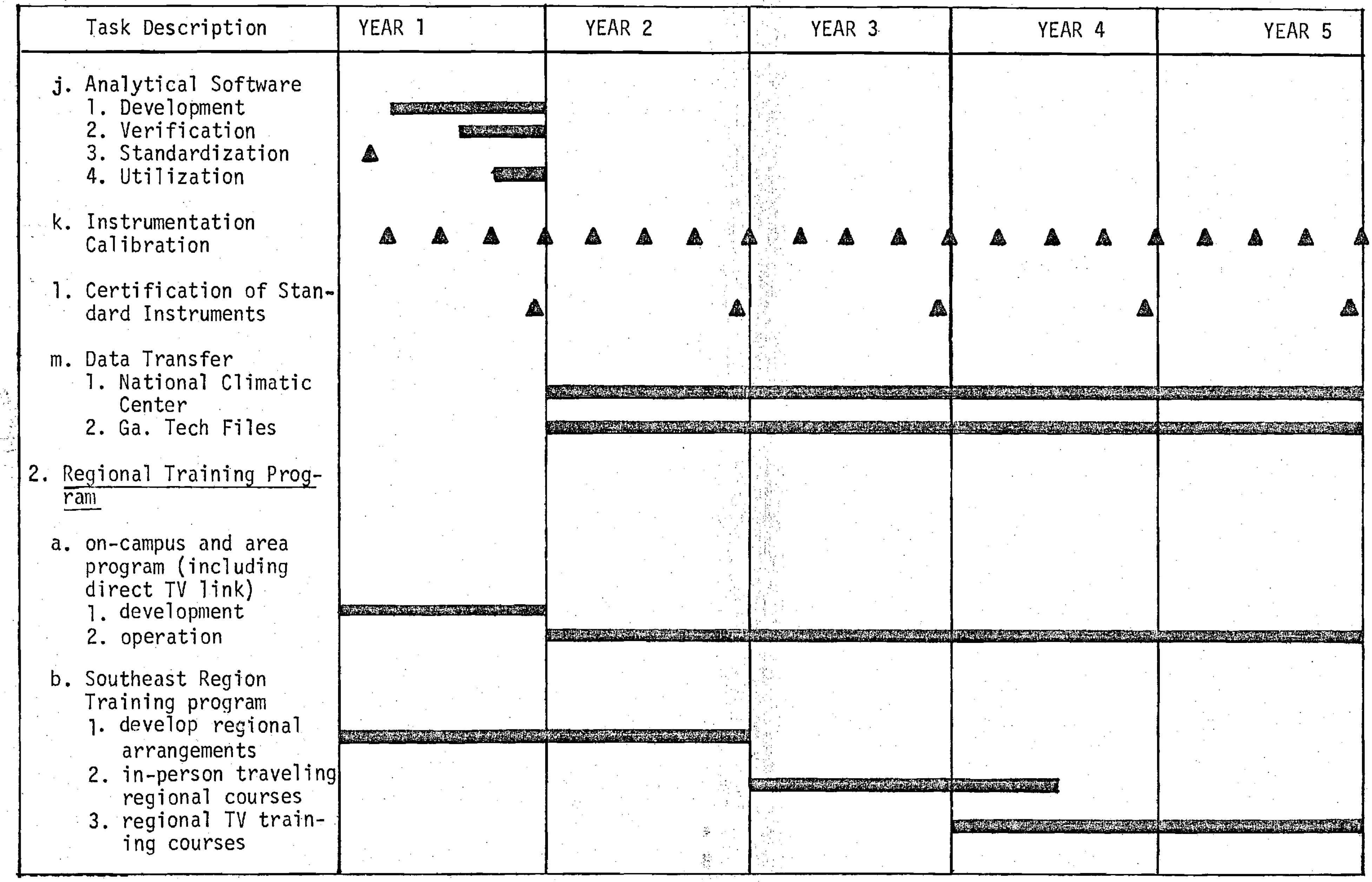


Figure 2.1 - (Cont'd.)

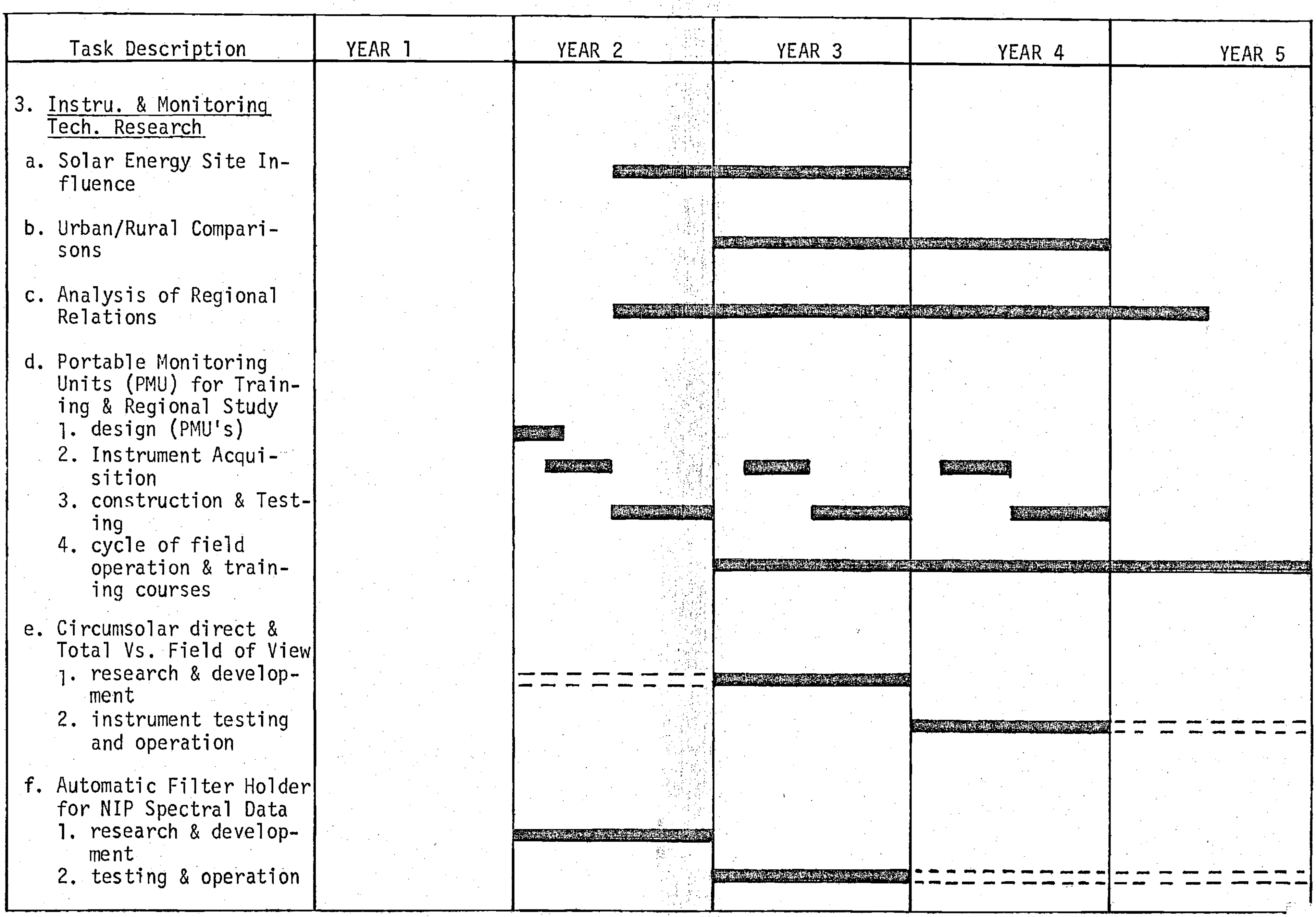
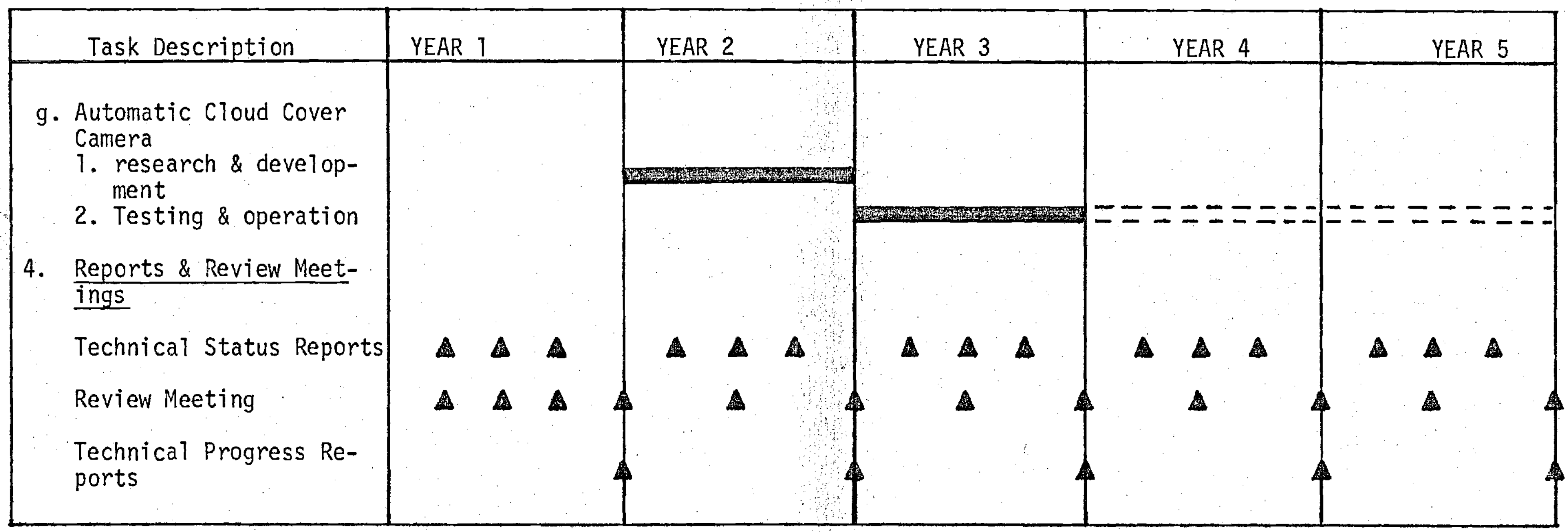


Figure 2.1 - (Cont'd.)



ORO/5604-78/1

PROGRAM FOR SOLAR ENERGY METEOROLOGICAL RESEARCH AND TRAINING SITE (REGION 3)

Quarterly Technical Status and
Contract Management Report

C. G. Justus, Principal Investigator

Georgia Institute of Technology
Atlanta, GA 30332

January, 1978

Report Period October 1, 1977 - December 31, 1977

PREPARED FOR THE UNITED STATES
DEPARTMENT OF ENERGY

DIVISION OF SOLAR ENERGY

UNDER GRANT EG-77-G-05-5604

Georgia Tech Project E-16-630

1. PROJECT OBJECTIVES

This broad program of solar energy and meteorological monitoring, training, and research has the following main objectives for the proposed 5 years duration:

(1) to provide for the Southeast Region (Region 3) a set of continuously monitored and quality controlled data on solar radiation and atmospheric phenomena related to solar energy collection, conversion, and sotrage, and to relate these to the extensive ongoing solar energy research and engineering projects carried out by Georgia Tech and in the Southeast Region.

(2) by analysis of monitoring results at two sites (on campus, adjacent to the Georgia Tech thermal Test facility and off-campus adjacent to the Shenandoah Solar Total Energy Site), determine: a) optimum siting of solar radiation and meteorological monitoring instruments relative to solar energy systems to provide the most representative site data with the least influence from the solar collector systems, b) adequacy and representativeness for the Southeast Region of various methodologies for relating easily measured phenomena (minutes of sunshine, cloud cover, etc.) to engineering quality solar radiation data (direct, diffuse, and global insolation, etc.).

(3) to establish and maintain a training program which will allow: a) undergraduate and graduate engineering students, through elective or minor courses, to become informed in the areas of meteorology and atmospheric science as they relate to solar and wind energy, b) graduate students in the atmospheric sciences to become informed of the specific requirements of monitoring, analysis, interpretation and presentation of meteorological information related to engineering aspects of solar and wind

energy, c) professionals in various fields, through short courses and seminars, to become familiar with the new and rapidly developing aspects of solar energy engineering and technology, especially the radiation monitoring and meteorological aspects of this field.

(4) through cooperation in the 3/2 dual degree program, the National Consortium for Graduate Degrees for Minorities in Engineering and other academic programs, enhance the opportunities for minorities (especially Black American and Puerto Ricans) and women in the solar energy engineering and technology field.

(5) instrumentation and monitoring techniques research and development to enhance the engineering applicability of the solar radiation and meteorological monitoring and to provide better instructional tools through low cost instrument systems for educational purposes.

(6) to investigate, with the fixed site instruments and the portable monitoring units (PMU's), the influence of urban haze and aerosols as well as the high levels of natural turbidity which occur in parts of the Southeast region, and with the PMU's to sample the effects on solar radiation of a wide variety of geography (which spans coastal, piedmont plains, and mountainous within the Southeast region).

2. PROJECT PLAN

A. Research Approach and Definition of Tasks

The proposed project plan is divided into three major tasks, each with several subtasks, as follows:

Task 1: Solar Radiation and Meteorological Monitoring Program

This task includes acquisition, initial calibration, and installation of the solar radiation and meteorological instrumentation at the on-campus (Solar Thermal Test Facility/Wind Turbine Test Facility) site and the off-campus (Shenandoah Georgia Solar Total Energy Project) site. Existing and new instrumentation at these sites will be combined and interfaced through data loggers and magnetic tape recording into a form which can be processed, summarized, and formatted by the main campus computer (CYBER 70/74 system). Annual calibration of the instrumentation, against national standards where appropriate, will be carried out, as well as more frequent field calibration of the radiation monitoring instruments. A carefully monitored program of daily instrument inspection and routine maintenance will also be carried out. The detailed outline of the various subtasks under Task 1 is as follows:

a. Based on the proposed variables to be monitored, the Instrumentation Network Design will be laid out using equipment assigned by Georgia Tech for use on this program and additional units to be purchased with the sponsor's approval.

b. Using the preliminary network design, the Selection, Order, and Delivery will be based on recommendations made at the preliminary review meeting of all of the principal investigators.

c. Before an instrument or support unit is put into service, each piece of equipment will be examined and subjected to an Instrument Check and Certification for conformation to Georgia Tech and vendor specifications.

Instruments which fail to pass inspection will be returned to the vendor for replacement.

d. The design, fabrication, and installation of the Auxiliary Hardware which will house and/or support the instrumentation will be according to recommendations in the above articles, of the respective vendors, and to experience gained through use of similar apparatus.

e. The Relocation of Existing Instruments will be performed expeditiously to prevent a loss of data in the present continuous monitoring system. Exposure and operation of the solar radiation and meteorological monitoring instruments will be in accordance with criteria and guidelines published by the WMO (1971) and the IGY (1958).

f. The Temporary Data Acquisition System will be used until the permanent system can be installed. This system is now in use with the instruments in "e".

g. The Instrumentation will be installed and calibrated after it is received and certified.

h. Campus Site Monitoring for the total system is scheduled to begin during the last month of Year 1, but a continuous monitoring system will have been in use for the entire period.

i. The Shenandoah Monitoring System will be used for the entire period after the "Sandia Solar Monitor System" is installed. This basic instrument package will be augmented by additional equipment. Data from the Shenandoah System will be logged on cassette tape. It will then be reformatted and merged with the campus site monitoring data on the CYBER system and put on magnetic tape.

j. Analytical Software will be developed in a standard format which will be used for all research sites. This format was selected at the project directors meeting in Washington, D.C. Data will be taken for analysis

to the CYBER 70/74 computer for transfer to the standard format and storage in this format on magnetic tape, and for transmittal of the raw and summarized data to the National Climatic Center in Asheville.

k. An Instrumentation Calibration by use of a set of special instruments or by techniques specified by the instrument vendor will be performed quarterly to verify instrument accuracy and to establish a permanent record of possible instrument degradation which would affect the acquired data.

l. At the end of each phase of the program, the set of standards would be taken to the Solar Radiation Calibration Facility in Denver, Colorado for Certification of Standard Instruments.

m. The Data Transfer to the National Climatic Center is scheduled to begin on a monthly basis at the end of Year 1 and would continue for the next 48 months. The data will also be stored at Georgia Tech.

Task 2: Solar Energy/Meteorology Training Program

This task involves development and implementation of on-campus, immediate area, and regional training. Existing graduate courses in general meteorology and boundary layer meteorology will be expanded by a new graduate course (open to seniors) in the area of meteorology for solar and wind energy. This course will include training in instrumentation, data acquisition, reduction and analysis. With the formation of an Atmospheric Sciences academic program anticipated to begin in September 1978, this academic curriculum will offer engineers and engineering technologists the opportunity to learn, as a minor or elective course basis, fundamentals of meteorology as it applies to solar energy engineering and technology. It will also allow meteorologists and atmospheric science students in the new program to interact with and learn about the engi-

neering problems and needs related to solar energy technology. This academic program and related short courses for professionals will be made available as appropriate through a unique instructional TV system to become operational at Georgia Tech in September 1978. A "traveling course" to be put on as a short course or a one quarter course at regional colleges will also be implemented. Initially this will be conducted by Georgia Tech personnel. Later, as arrangements are worked out and the local college has personnel trained to proctor or tutor the course, this will be carried via the TV system, either on a video cassette delivery basis, or if the system is developed, via a satellite TV link.

Task 3: Instrumentation and Monitoring Techniques Research

Various research and development aspects related both to the monitoring and the training program, will be carried out under this task. The location of the two monitoring sites - one on-campus within about two miles from the heart of downtown Atlanta, one at the new town Shenandoah site, about 45 miles from Atlanta - will allow evaluation of urban/rural differences, especially related to urban haze and aerosols. The exposure of the instruments adjacent to the Solar Thermal Test Facility and Wind Turbine Test Facility at Georgia Tech will allow evaluation of potential effects on temperature, moisture, and air flow near such facilities. Hence optimum locations will be evaluated for instruments near solar energy facilities, to provide maximum degree of representativeness and minimum influence from the solar energy system on the meteorological measurements. Many models have been proposed in which various meteorological and simply measured radiation parameters (sunshine hours, temperature, cloud cover, solar declination, etc.) can be used to estimate engineering quality insolation (global and direct insolation, global on inclined surfaces, etc.). Some of these methods are those of Fritz (1957), Angstrom (1956), Black et al (1954), Glover and McCulloch (1958), Sabbagh et al (1977), Liu and Jordan (1960),

Whillier (1956) Bennett (1965), Swartman and Ogunladeo (1967), Reddy (1971a, 1971b), Norris (1966), Masson (1966), Atwater (1974), Lumb (1964), L'Vova (1972), Machta (1974), Paltridge (1974), Lin (1973), and Randall et al (1977). Through NOAA (machta, private communication) a set of linear regression coefficients is being developed for the 26 rehabilitated solar radiation data stations. Using this model, the National Climatic Center will prepare, by November 1977, solar radiation estimates for 200 stations in the U.S. These data will be put on magnetic tape in SOLMET format. The data from the on-campus and off-campus monitoring sites as well as from the 5 Southeastern sites in the new 35 site NOAA network (Riches, 1975) will be used to study regional relationships between simply monitored parameters and solar radiation data for engineering purposes. Results of the contract study resulting from the recent RFP to Perform a Solar Radiation Data Forecast and Interpolation Analysis will also be applied in this study. Emphasis will be on study of the influence of turbidity (high in parts of the Southeast region), and regional geography (which spans coastal, piedmont plains, and mountain areas). During the second and subsequent years up to three low cost portable monitoring units will be designed and built. These units will be used in the training program as instructional systems for the traveling course to regional colleges. Data from these units will also be used in the analysis of methods to relate simple measured parameters to engineering quality insolation data for the region. Other instrument and monitoring techniques for which research and development projects are envisioned will include:

a. an automatic filter changing wheel for the normal incidence pyrheliometer (to automatically switch on a 1/minute or less basis between clear, OG1, RG2, and RG8 filters),
b. circumsolar radiation with the Lawrence Berkley Labs circumsolar telescope, currently on campus and projected to remain here throughout at least a portion of this project, and

c. an automatic wide field of view camera system to provide a film record of cloud cover conditions.

3. ADMINISTRATIVE STATUS

A. General

The technical management, direction, and coordination of this program is being carried out through the School of Aerospace Engineering (AE) of the Georgia Institute of Technology (Georgia Tech). Contribution to the program will include the Solar Energy and Materials Technology Division (SEMTD) of the Applied Sciences Lab (ASL) and the Radar and Instrumentation Lab (RAIL) of the Georgia Tech Engineering Experiment Station (EES), and the School of Electrical Engineering (EE). It is anticipated that, beginning in September 1978, the academic program involving meteorology and atmospheric science will be offered through the School of Geophysical Science and its Atmospheric Program which is currently being planned.

B. Project Team Members and Organization

The interdisciplinary team for this project are: Dr. C. G. Justus, School of AE and School of Geophys. Sci., principal investigator; with team members Dr. J. I. Craig, School of AE; Mr. A. T. Sales, SEMTD, EES; Dr. J. H. Scholag, School of EE; Ms. Joan Wood, EE; Dr. J. I. Metcalf, RAIL, EES; and consultants Dr. J. R. Williams, College of Engineering, and Mr. J. D. Walton, SEMTD, EES.

As described in Section 2, the three main technical tasks proposed for the project are: Task 1 - Solar Radiation and Meteorological Monitoring (on campus site and Shenandoah site), Task 2 - Solar Energy/Meteorology Training Program, and Task 3 - Instrumentation and Monitoring Techniques Research.

The proposed project team organization is shown in Figure 3.1. Each team member will make contributions as necessary to all of the tasks - both monitoring, training, and research. Task 1 will have co-task leaders (Sales and Craig), as will Task 2 (Justus and Metcalf). Task 3 leadership will be provided by Dr. Schlag. Each task leader or co-leader will be responsible for performance of functions related to that task. Overall project management and direction will be provided by the Principal Investigator, Dr. Justus.

C. Administrative Actions

Support personnel who have been assigned specific work tasks on the project are Dr. Amir Mikhail, post doctoral assistant, data acquisition software; Mr. David Rawlings, research technologist, electromechanical assistance; Mr. John Caudell, research associate, electronics technician; Mr. George Halstead, shop technician; Mr. Bill Meyer, programming assistant; Mr. Dennis Tucker, graduate research assistant, Mr. Frank Zegler and Ms. Denise Graber co-op assistants.

It is currently anticipated that the appointment of Dr. Justus will be transfered from the present joint A.E./Geophys. Sci. to full time Geophysical Science prior to the beginning of the second year of this project. Appointments of secretarial and student assistance may also be change to Geophysical Science. Dr. Craig will continue to be appointed through Aerospace Engineering.

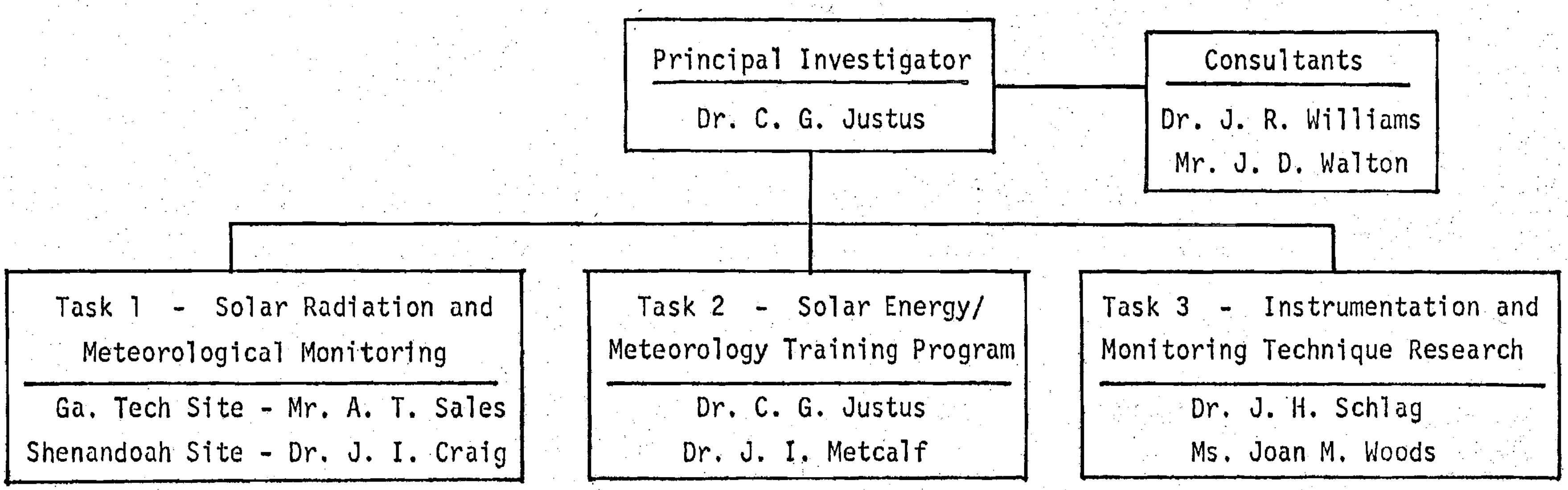


Figure 3.1 - Project Organization Chart

4. PROGRESS TO DATE

<u>Task 1</u>: Solar Radiation and Meteorological Monitoring Program

a. The instrumentation network design is essentially complete. On campus monitoring instruments will be mounted on a 100 ft Forest Service type tower at the northwest corner of the Solar Thermal Test Facility (STTF) site. This tower, to be obtained through surplus, replaces the use of the "south tower" originally proposed for the STTF site, which has since been cancelled. Location of the tower on the Solar Thermal Test Facility Site is shown in Figure 4.1. A diagram of the tower is shown in Figure 4.2.

b. On campus continuous monitoring instrumentation on the tower will consist of: global, diffuse, direct, global spectral, global tilted, direct spectral, UV and incoming IR radiation; sunshine duration; wind speed and direction (2 levels); temperature and humidity (2 levels); station pressure; and precipitation. At the Shenandoah site continuous monitoring instrumentation will consist of: global, diffuse, direct, global spectral, global tilted, direct spectral, and IR incoming radiation; pressure, temperature, humidity, wind speed, wind direction, and rainfall. These instruments, together with some of the research instrumentation (voltz photometers, nephelometer, dustfall samplers) have been ordered (except for IR incoming, CSIRO IR radiometer instruments, the buy for which is being coordinated through SERI).

c. Instrument check and certification awaits instrument acquisition.

d. Preliminary ideas on auxilliary hardware have been worked out. Design and fabrication will begin in following project periods.

e-h. No work in these areas was scheduled during the report quarter.

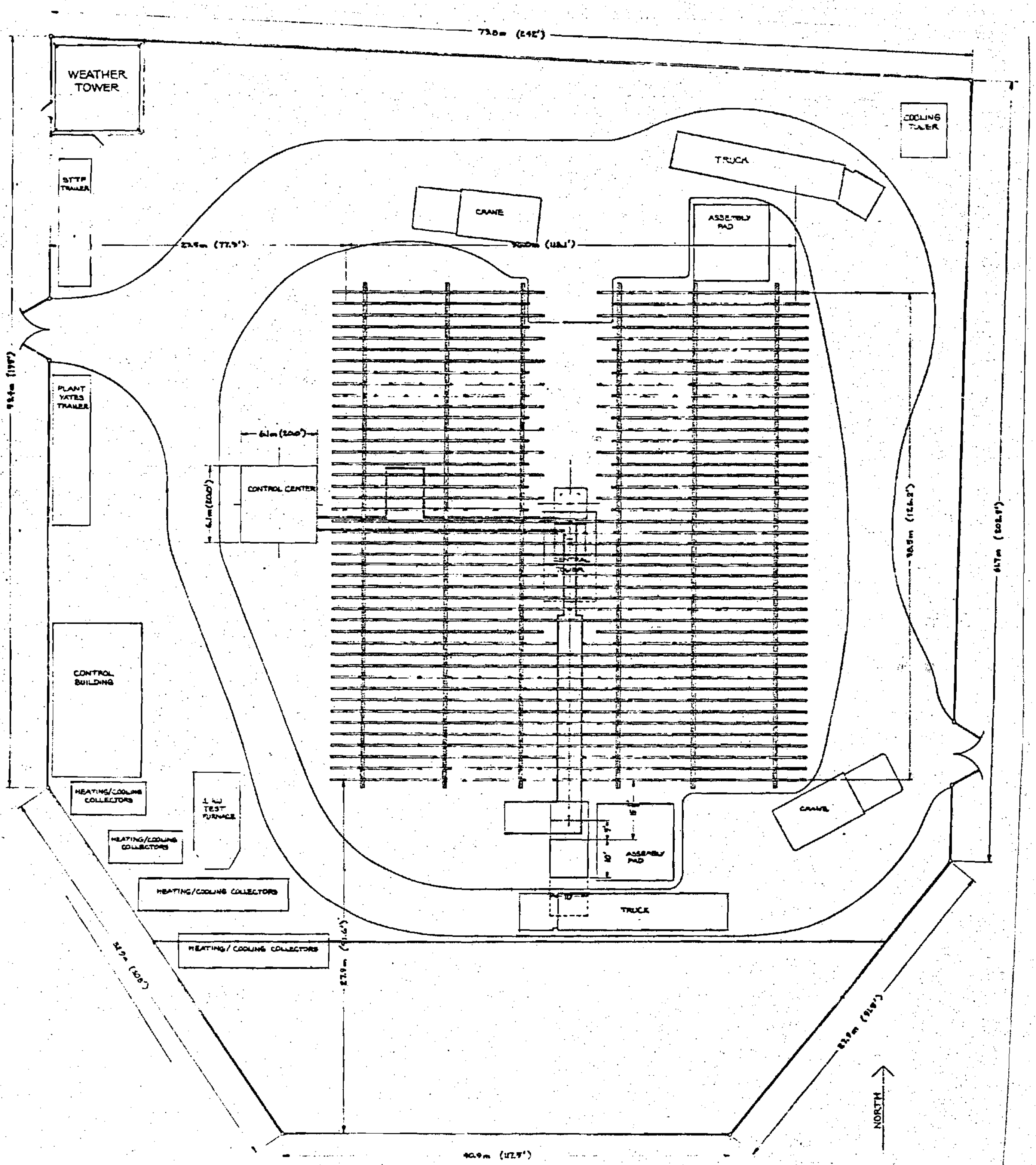


Figure 4.1 - Location of 100 ft Forest Service Tower (labeled "Weather Tower") on the STTF Site.

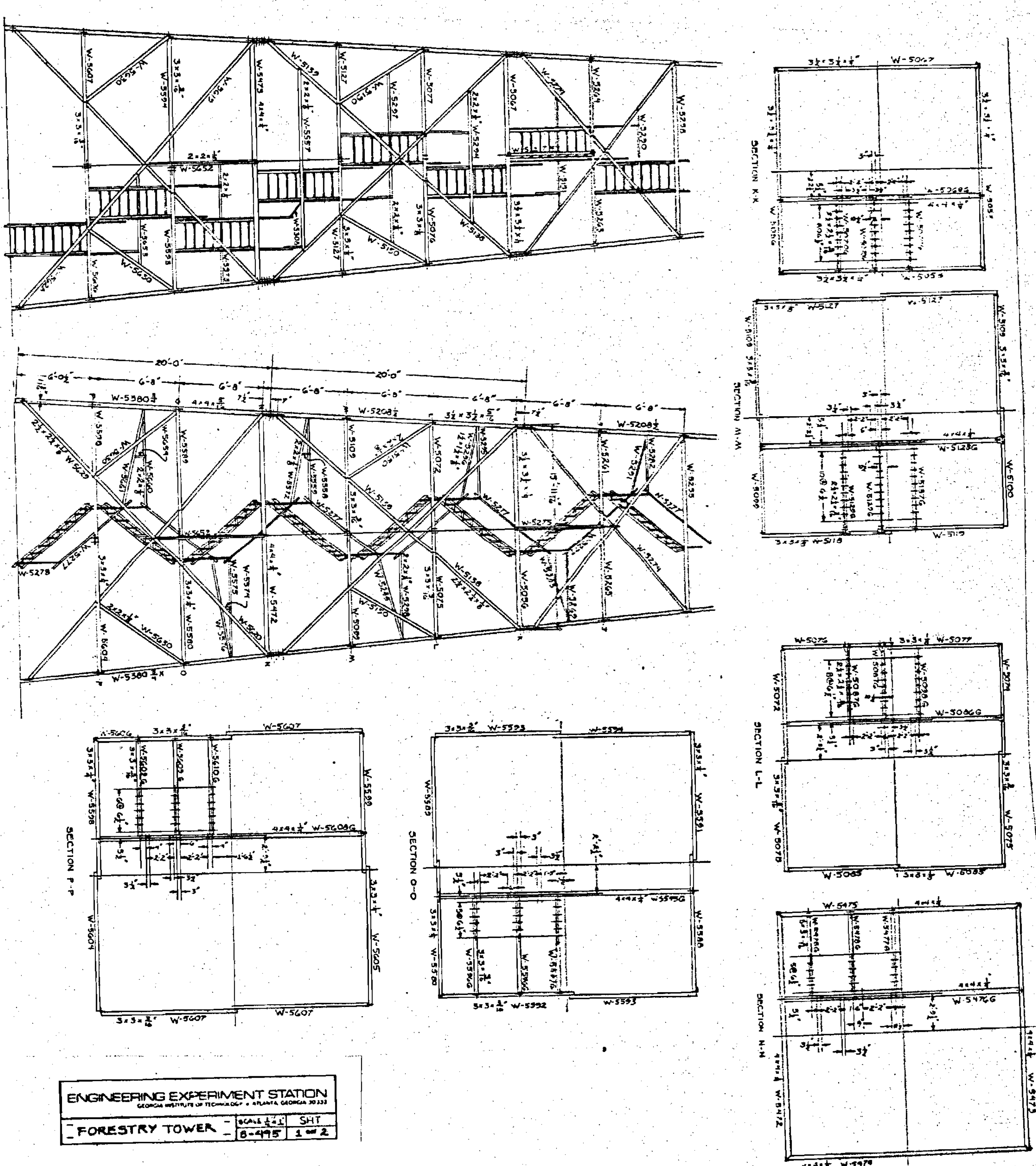


Figure 4.2 (a) Lower Section of Forest Service Tower.

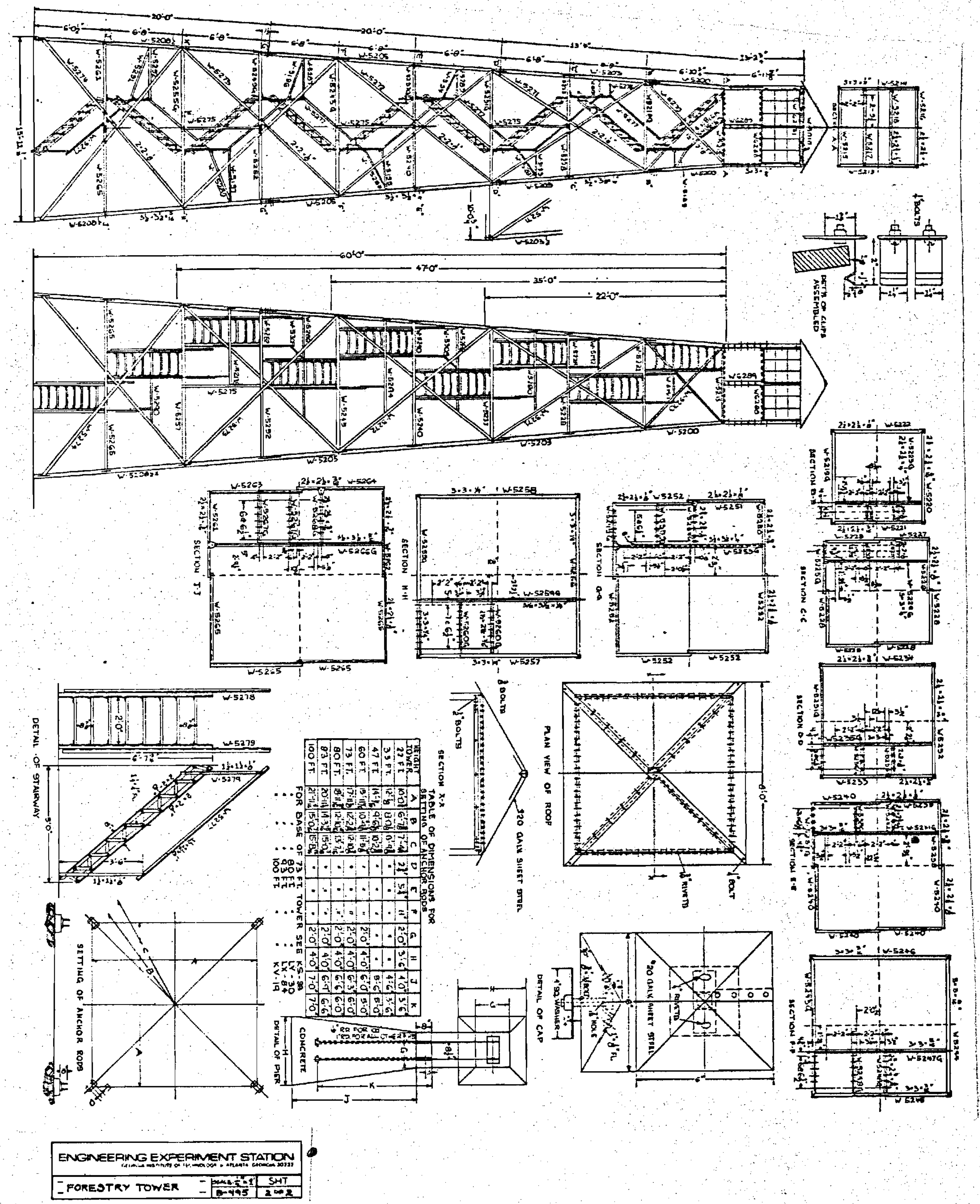


Figure 4.2(b) - Upper Section of Forest Service Tower.

i. Monitoring and recording of 8 parameters has begun at Shenandoah. These will be augmented as the additional instruments arrive. A 16 channel capacity data logger is being provided through Sandia to replace the present 8 channel logger.

j-m. No work in these areas was scheduled during the report quarter.

Task 2: Solar Energy/Meteorology Training Program

A new academic program in atmospheric sciences under the School of Geophysical Sciences has been planned and submitted for approval by the Georgia Tech Academic Senate. The proposed Atmospheric Sciences program will consist of three elements: 1) a set of required background undergraduate courses in Geophysical Sciences which cover introductory aspects of the geophysics of the solid earth, the hydrosphere, and the atmosphere, 2) a set of required Atmospheric Science program courses at the graduate level, introducing the three areas of atmospheric dynamics, atmospheric chemistry, and physical meteorology, 3) a set of optional courses whereby a student in the Atmospheric Sciences program may specialize in a track for atmospheric dynamics, atmospheric chemistry, or physical meteorology.

Three proposed courses in this program are especially relevant to solar radiation monitoring aspects: Geo.S. 6930, 31, Physical Meteorology I, II, and Geo.S. 6932 Meteorology for Solar and Wind Energy. Brief course descriptions for these are:

Geo.S. 6930, Physical Meteorology I - Physical processes in the atmosphere. Effects of atmospheric composition and structure on solar and terrestrial radiation; physics of clouds, precipitation, and thunderstorms.

Geo.S. 6931, Physical Meteorology II - Laboratory course in atmospheric physics. Experiments with state-of-the-art instrumentation for observing and measuring physical properties of atmospheric radiation, aerosols, clouds, and precipitation.

Geo.S. 6932, Meteorology for Solar and Wind Energy - Solar radiation instruments, measurement, and calibration techniques. Atmospheric attenuation, effects of clouds and turbidity. Meteorological factors and wind energy system design, performance evaluation, and siting.

Task 3: Instrumentation and Monitoring Techniques Research

The integrating nephelometer, volz sun photometers, and directional dustfall sampling equipment have been ordered. These will be used to study urban/rural differences in turbidity, visibility, haze/fog, and small and large particulates by comparisons between the urban on-campus site and the rural Shenandoah site. Most of the other Task 3 effort, other than research planning, will be second year activity.

5. FINANCIAL STATUS

Financial status is outlined in the attached Contract Management Summary Report. Expenditures and manpower will more closely approach the projected values as instrument acquisition costs and heavier manpower needs of instrument installation are reflected in subsequent quarters. Tables 1 and 2 give data on the current (Year 1) budget and projections for continued funding of the additional four years.

Table 1
Complete Description of Direct Labor Category Data

Labor Category	Year 1 hrs	Year 1 Rate $/hr	Year 1 Cost $	Year 2 hrs	Year 2 Rate $/hr	Year 2 Cost $	Year 3 hrs	Year 3 Rate $/hr	Year 3 Cost $	Year 4 hrs	Year 4 Rate $/hr	Year 4 Cost $	Year 5 hrs	Year 5 Rate $/hr	Year 5 Cost $
Professor/Principal Research Engineer	936	17.90	16,754	936	18.80	17,597	936	19.73	18,467	936	20.72	19,394	936	21.76	20,367
Associate Professor/ Sr. Res. Engineer	1352	14.11	19,077	1352	14.82	20,037	1352	15.56	21,037	1352	16.33	22,078	1352	17.15	23,187
Research Engineer	1040	10.93	11,367	1040	11.48	11,939	1040	12.05	12,532	1040	12.65	13,156	1040	13.29	13,822
Assistant Research Engineer	208	8.67	1,803	208	9.10	1,893	208	9.56	1,988	208	10.04	2,088	208	10.54	2,192
Senior Technician	1040	10.77	11,201	520	11.31	5,881	520	11.87	6,172	520	12.47	6,484	520	13.09	6,807
Technician	1040	7.50	7,800	1040	7.88	8,195	1040	8.27	8,601	1040	8.68	9,027	1040	9.12	9,485
Machinist	700	6.93	4,851	208	7.28	1,514	208	7.64	1,589	208	8.02	1,668	208	8.42	1,751
Secretarial/ Clerical	730	4.66	3,402	730	4.89	3,570	730	5.14	3,752	730	5.39	3,935	730	5.66	4,132
Graduate Research Assistant	2080	5.90	12,272	2080	6.20	12,896	2080	6.50	13,520	2080	6.83	14,206	2080	7.17	14,914
CO-OP Student Assistant	2080	4.52	9,402	2080	4.75	9,880	2080	4.98	10,358	2080	5.23	10,878	2080	5.49	11,419
TOTAL			$97,929			$93,402			$98,016			$102,914			$108,076

Table 2
Projected 5 Year Budget Summary

	Year 1	Year 2	Year 3	Year 4	Year 5
Personal Services	$ 97,929	$ 93,402	$ 98,016	$102,914	$108,076
Overhead (68%)	66,592	63,513	66,651	69,982	73,492
Retirement (9.35% faculty & staff wages)	7,130	6,604	6,932	7,277	7,643
Equipment	73,280	22,000	14,001	8,217	3,800
Materials and Supplies	5,750	5,500	5,000	5,000	5,000
Travel	2,900	2,500	2,600	2,750	2,900
Computer	5,000	5,250	5,500	5,800	6,100
Reports and Photolab	1,200	1,250	1,300	1,350	1,450
	$259,781	$200,019	$200,000	$203,290	$208,461
less matching	59,781	19		3,290	8,461
DOE Budget	$200,000	$200,000	$200,000	$200,000	$200,000

FORM ERDA 536
(6/30/76)

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

CONTRACT MANAGEMENT SUMMARY REPORT

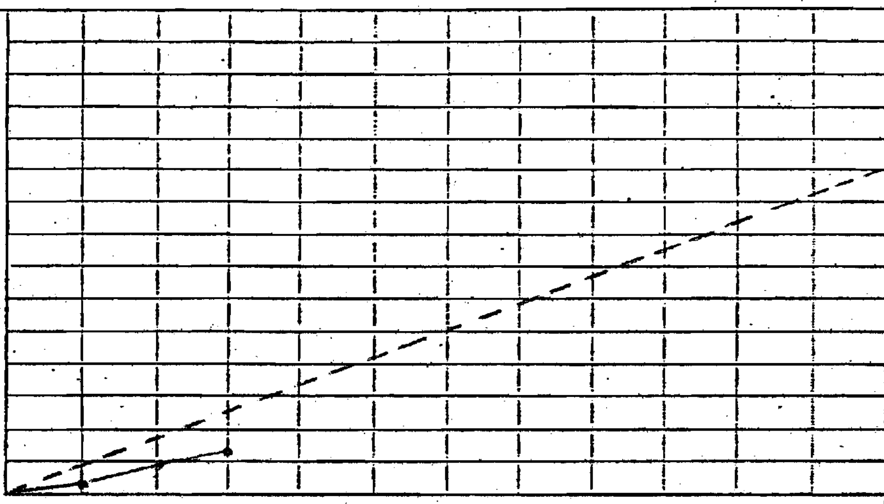
FORM APPROVED

1. Contract Identification Program for Solar Energy Meteorological Research and Training Site (Region 3)	2. Reporting Period 10/1/77 through 12/31/77	3. Contract Number EG-77-G-05-5604
4. Contractor (name and address) School of AE, Georgia Tech Atlatta, GA 30332		5. Contract Start Date 9/30/77
		6. Contract Completion Date 9/29/78

7. Months	O	N	D	J	F	M	A	M	J	J	A	S	8. FY 78

Cost Status

Cumulative Costs $1,000



e. Actual Costs Prior FYs: 0

f. Planned Costs Prior FYs: 0

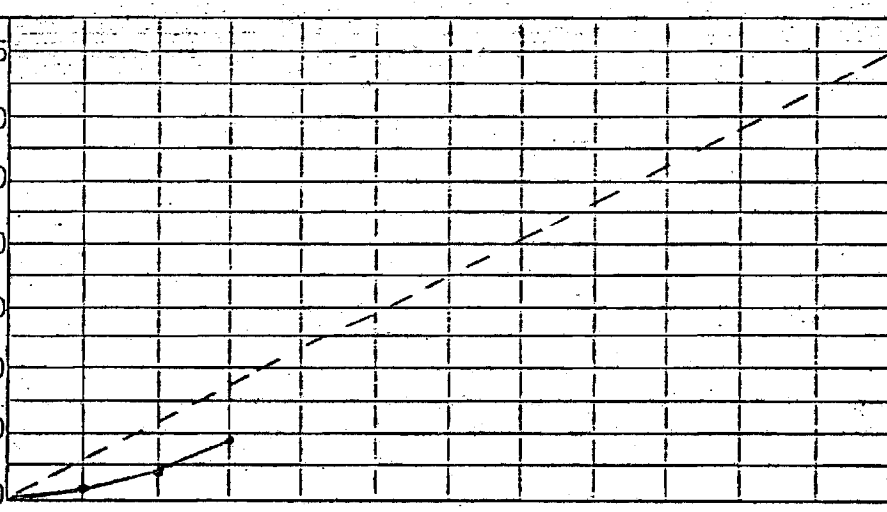
g. Total Projected Accrued Costs for Contract: $200,000

h. Total Contract Value: $200,000

Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S
b. Planned	16.7	33.3	50.0									
c. Actual	4.1	18.6	25.3									
d. Variance	12.6	14.7	24.7									

Manpower Status

Cumulative Man Months



e. Actual Manpower Prior FYs: 0

f. Planned Manpower Prior FYs: 0

g. Total Projected Manpower for Contract: 65 man months

h. Total Contract Manpower: 65 man months

Manpower	O	N	D	J	F	M	A	M	J	J	A	S
b. Planned	5.4	10.8	16.3									
c. Actual	1.7	4.1	8.7									
d. Variance	3.7	6.7	7.6									

Major Milestone Status

See attached Detailed Milestone Chart

Remarks

Signature of Contractor's Project Manager and Date 2/6/78

14. Signature of Government Technical Representative and Date

Milestone Chart

Task Description	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
1. Solar Radiation & Meteorological Monitoring					
a. 1. Instrument Network Design					
2. Modifications as needed					
b. Selection, order, and delivery of instru.					
c. Instrument check and certification					
d. Auxiliary Hardware 1. Design 2. Mat. Acquisition 3. Fabrication 4. Installation					
e. Campus Site Mod. and preparation					
f. Relocation of Existing Instruments 1. Installation 2. Calibration 3. Temp. Data Acquisition					
g. Instrumentation 1. Installation 2. Electronic and Meteorol. Calibration					

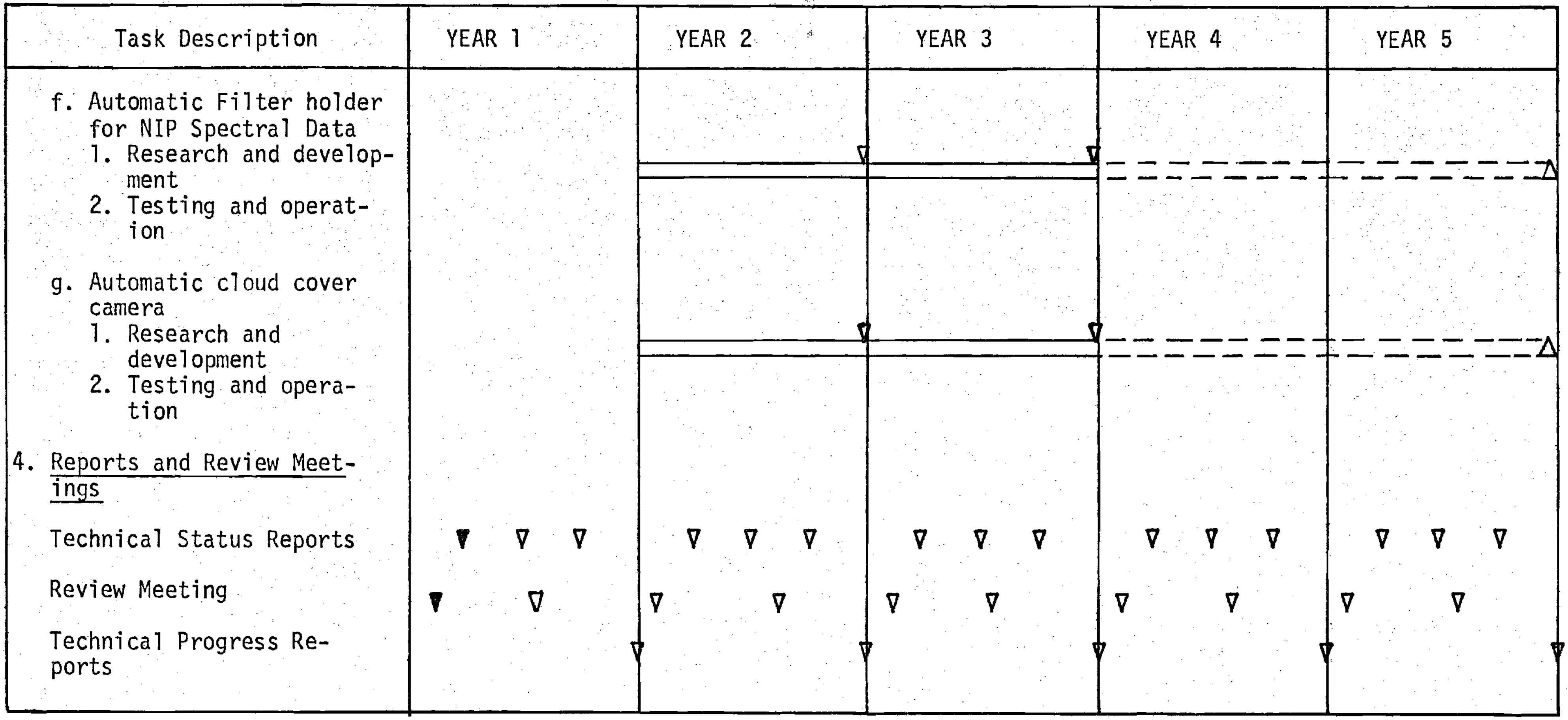
Milestone Chart (Cont'd.)

Task Description	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
h. Campus Site Monitor					
i. Shenandoah Monitor					
j. Analytical Software 1. Standardization 2. Development 3. Verification 4. Utilization 5. Modifications as needed					
k. Radiation Sensor Calibration					
l. Certification of Standard Radiation Instruments					
m. Data Transfer 1. National Climatic Center 2. Ga. Tech Files					
2. <u>Regional Training Program</u>					
a. On-campus and area program (including direct TV link) 1. Development 2. Operation					

Milestone Chart (Cont'd)

Task Description	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
b. Southeast Region Training Program 1. Develop regional arrangements 2. In-persion traveling regional courses 3. Regional TV training courses					
3. <u>Instrument and Monitoring Technical Research</u>					
a. Solar Energy Site Influence					
b. Urban/Rural Comparisons					
c. Analysis of Regional Relations					
d. Portable Monitoring Units (PMU) for Training and Regional Study 1. Design (PMU's) 2. Instrument acquisition 3. Construction and testing 4. Cycle of field operation and training courses		Unit 1	Unit 2	Unit 3	
e. Circumsolar Direct and Total vs. Field of View 1. Research and development 2. Instrument testing and operation					

Milestone Chart (cont'd)



ORO/5604-78/2

PROGRAM FOR SOLAR ENERGY METEOROLOGICAL RESEARCH AND TRAINING SITE (REGION 3)

Quarterly Technical Status and
Contract Management Report

C. G. Justus, Principal Investigator

Georgia Institute of Technology
Atlanta, GA 30332

April, 1978

Report Period January 1, 1978 - March 31, 1978

PREPARED FOR THE UNITED STATES
DEPARTMENT OF ENERGY

DIVISION OF SOLAR ENERGY

UNDER GRANT EG-77-G-05-5604

Georgia Tech Project E-16-630

1. PROJECT OBJECTIVES

This broad program of solar energy and meteorological monitoring, training, and research has the following main objectives for the proposed 5 years duration:

(1) to provide for the Southeast Region (Region 3) a set of continuously monitored and quality controlled data on solar radiation and atmospheric phenomena related to solar energy collection, conversion, and storage, and to relate these to the extensive ongoing solar energy research and engineering projects carried out by Georgia Tech and in the Southeast Region.

(2) by analysis of monitoring results at two sites (on campus, adjacent to the Georgia Tech thermal Test facility and off-campus adjacent to the Shenandoah Solar Total Energy Site), determine: a) optimum siting of solar radiation and meteorological monitoring instruments relative to solar energy systems to provide the most representative site data with the least influence from the solar collector systems, b) adequacy and representativeness for the Southeast Region of various methodologies for relating easily measured phenomena (minutes of sunshine, cloud cover, etc.) to engineering quality solar radiation data (direct, diffuse and global insolation, etc.).

(3) to establish and maintain a training program which will allow: a) undergraduate and graduate engineering students, through elective or minor courses, to become informed in the areas of meteorology and atmospheric science as they relate to solar and wind energy, b) graduate students in the atmospheric sciences to become informed of the specific requirements of monitoring, analysis, interpretation and presentation of meteorological information related to engineering aspects of solar and wind

energy, c) professionals in various fields, through short courses and seminars, to become familiar with the new and rapidly developing aspects of solar energy engineering and technology, especially the radiation monitoring and meteorological aspects of this field.

(4) through cooperation in the 3/2 dual degree program, the National Consortium for Graduate Degrees for Minorities in Engineering and other academic programs, enhance the opportunities for minorities (especially Black American and Puerto Ricans) and women in the solar energy engineering and technology field.

(5) instrumentation and monitoring techniques research and development to enhance the engineering applicability of the solar radiation and meteorological monitoring and to provide better instructional tools through low cost instrument systems for educational purposes.

(6) to investigate, with the fixed site instruments and the portable monitoring units (PMU's), the influence of urban haze and aerosols as well as the high levels of natural turbidity which occur in parts of the Southeast region, and with the PMU's to sample the effects on solar radiation of a wide variety of geography (which spans coastal, piedmont plains, and mountainous within the Southeast region).

2. PROJECT PLAN

A. Research Approach and Definition of Tasks

The proposed project plan is divided into three major tasks, each with several subtasks, as follows:

Task 1: Solar Radiation and Meteorological Monitoring Program

This task includes acquisition, initial calibration, and installation of the solar radiation and meteorological instrumentation at the on-campus (Solar Thermal Test Facility/Wind Turbine Test Facility) site and the off-campus (Shenandoah Georgia Solar Total Energy Project) site. Existing and new instrumentation at these sites will be combined and interfaced through data loggers and magnetic tape recording into a form which can be processed, summarized, and formatted by the main campus computer (CYBER 70/74 system). Annual calibration of the instrumentation, against national standards where appropriate, will be carried out, as well as more frequent field calibration of the radiation monitoring instruments. A carefully monitored program of daily instrument inspection and routine maintenance will also be carried out. The detailed outline of the various subtasks under Task 1 is as follows:

a. Based on the proposed variables to be monitored, the Instrumentation Network Design will be laid out using equipment assigned by Georgia Tech for use on this program and additional units to be purchased with the sponsor's approval.

b. Using the preliminary network design, the Selection, Order, and Delivery will be based on recommendations made at the preliminary review meeting of all of the principal investigators.

c. Before an instrument or support unit is put into service, each piece of equipment will be examined and subjected to an Instrument Check and Certification for conformation to Georgia Tech and vendor specifications.

Instruments which fail to pass inspection will be returned to the vendor for replacement.

d. The design, fabrication, and installation of the Auxiliary Hardware which will house and/or support the instrumentation will be according to recommendations in the above articles, of the respective vendors, and to experience gained through use of similar apparatus.

e. Campus Site Modification and Preparation will be done as necessary to accomodate the new monitoring site and instrumentation.

f. The Relocation of Existing Instruments will be performed expeditiously to prevent a loss of data in the present continuous monitoring system. Exposure and operation of the solar radiation and meteorological monitoring instruments will be in accordance with criteria and guidelines published by the WMO(1971) and the IGY (1958).

g. The Instrumentation will be installed and calibrated after it is received and certified.

h. Campus Site Monitoring for the total system is scheduled to begin during the last month of Year 1, but a continuous monitoring system will have been in use for the entire period.

i. The Shenandoah Monitoring System will be used for the entire period after the "Sandia Solar Monitor System" is installed. This basic instrument package will be augmented by additional equipment. Data from the Shenandoah System will be logged on cassette tape. It will then be reformatted and merged with the campus site monitoring data on the CYBER system and put on magnetic tape.

j. Analytical Software will be developed in a standard format which will be used for all research sites. This format was selected at the project directors meeting in Washington, D. C. Data will be taken for analysis

to the CYBER 70/74 computer for transfer to the standard format and storage in this format on magnetic tape, and for transmittal of the raw and summarized data to the National Climatic Center in Asheville.

k. An <u>Instrumentation Calibration</u> by use of a set of special instruments or by techniques specified by the instrument vendor will be performed quarterly to verify instrument accuracy and to establish a permanent record of possible instrument degradation which would affect the acquired data.

l. At the end of each phase of the program, the set of standards would be taken to the Solar Radiation Calibration Facility in Denver, Colorado for <u>Certification of Standard Instruments</u>.

m. The <u>Data Transfer</u> to the National Climatic Center is scheduled to begin on a monthly basis at the end of Year 1 and would continue for the next 48 months. The data will also be stored at Georgia Tech.

<u>Task 2</u>: Solar Energy/Meteorology Training Program

This task involves development and implementation of on-campus, immediate area, and regional training. Existing graduate courses in general meteorology and boundary layer meteorology will be expanded by a new graduate course (open to seniors) in the area of meteorology for solar and wind energy. This course will include training in instrumentation, data acquisition, reduction and analysis. With the formation of an Atmospheric Sciences academic program anticipated to begin in September 1978, this academic curriculum will offer engineers and engineering technologists the opportunity to learn, as a minor or elective course basis, fundamentals of meteorology as it applies to solar energy engineering and technology. It will also allow meteorologists and atmospheric science students in the new program to interact with and learn about the engi-

neering problems and needs related to solar energy technology. This academic program and related short courses for professionals will be made available as appropriate through a unique instructional TV system to become operational at Georgia Tech in September 1978. A "traveling course" to be put on as a short course or a one quarter course at regional colleges will also be implemented. Initially this will be conducted by Georgia Tech personnel. Later, as arrangements are worked out and the local college has personnel trained to proctor or tutor the course, this will be carried via the TV system, either on a video cassette delivery basis, or if the system is developed, via a satellite TV link.

Task 3: Instrumentation and Monitoring Techniques Research

Various research and development aspects related both to the monitoring and the training program, will be carried out under this task. The location of the two monitoring sites - one on-campus within about two miles from the heart of downtown Atlanta, one at the new town Shenandoah site, about 45 miles from Atlanta - will allow evaluation of urban/rural differences, especially related to urban haze and aerosols. The exposure of the instruments adjacent to the Solar Thermal Test Facility and Wind Turbine Test Facility at Georgia Tech will allow evaluation of potential effects on temperature, moisture, and air flow near such facilities. Hence optimum locations will be evaluated for instruments near solar energy facilities, to provide maximum degree of representativeness and minimum influence from the solar energy system on the meteorological measurements. Many models have been proposed in which various meteorological and simply measured radiation parameters (sunshine hours, temperature, cloud cover, solar declination, etc.) can be used to estimate engineering quality insolation (global and direct insolation, global on inclined surfaces, etc.). Some of these methods are those of Fritz (1957), Angstrom (1956), Black et al (1954), Glover and McCulloch (1958), Sabbagh et al (1977), Liu and Jordan (1960),

Whillier (1956) Bennett (1965), Swartman and Ogunladeo (1967), Reddy (1971a, 1971b), Norris (1966), Masson (1966), Atwater (1974), Lumb (1964), L'Vova (1972), Machta (1974), Paltridge (1974), Lin (1973), and Randall et al (1977). Through NOAA (Machta, private communication) a set of linear regression coefficients is being developed for the 26 rehabilitated solar radiation data stations. Using this model, the National Climatic Center will prepare, by November 1977, solar radiation estimates for 200 stations in the U.S. These data will be put on magnetic tape in SOLMET format. The data from the on-campus and off-campus monitoring sites as well as from the 5 Southeastern sites in the new 35 site NOAA network (Riches, 1975) will be used to study regional relationships between simply monitored parameters and solar radiation data for engineering purposes. Results of the contract study resulting from the recent RFP to Perform a Solar Radiation Data Forecast and Interpolation Analysis will also be applied in this study. Emphasis will be on study of the influence of turbidity (high in parts of the Southeast region), and regional geography (which spans coastal, piedmont plains, and mountain areas). During the second and subsequent years up to three low cost portable monitoring units will be designed and built. These units will be used in the training program as instructional systems for the traveling course to regional colleges. Data from these units will also be used in the analysis of methods to relate simple measured parameters to engineering quality insolation data for the region. Other instrument and monitoring techniques for which research and development projects are envisioned will include:

a. an automatic filter changing wheel for the normal incidence pyrheliometer (to automatically switch on a 1/minute or less basis between clear, OG1, RG2, and RG8 filters),
b. circumsolar radiation with the Lawrence Berkley Labs circumsolar telescope, currently on campus and projected to remain here throughout at least a portion of this project, and

c. an automatic wide field of view camera system to provide a film record of cloud cover conditions.

3. ADMINISTRATIVE STATUS

No changes. Project team and organization is as shown in Figure 3.1. Joan Wood will be out on maternity leave during the following quarter.

4. PROGRESS TO DATE

<u>Task 1</u>: Solar Radiation and Meteorological Monitoring Program

a. The instrumentation network design is complete. Instrumentation for the parameters to be monitored is outlined in Table 4.1. At the time of the original proposal a "south tower" was planned at the Solar Thermal Test Facility on campus. It was originally proposed that monitoring instrumentation be at the top of this tower. When this south tower was cancelled, it was originally hoped that a replacement tower, at the northwest corner of the Solar Thermal Test Facility Site could be used instead. Preliminary estimates on acquisition and installation of a surplus Forest Service tower looked promising. However, when firm bids were received which were about 70% higher than preliminary estimates, this approach was abandoned. Instead, the monitoring site will now be located on a new instrument platform to be installed on the roof of the Civil

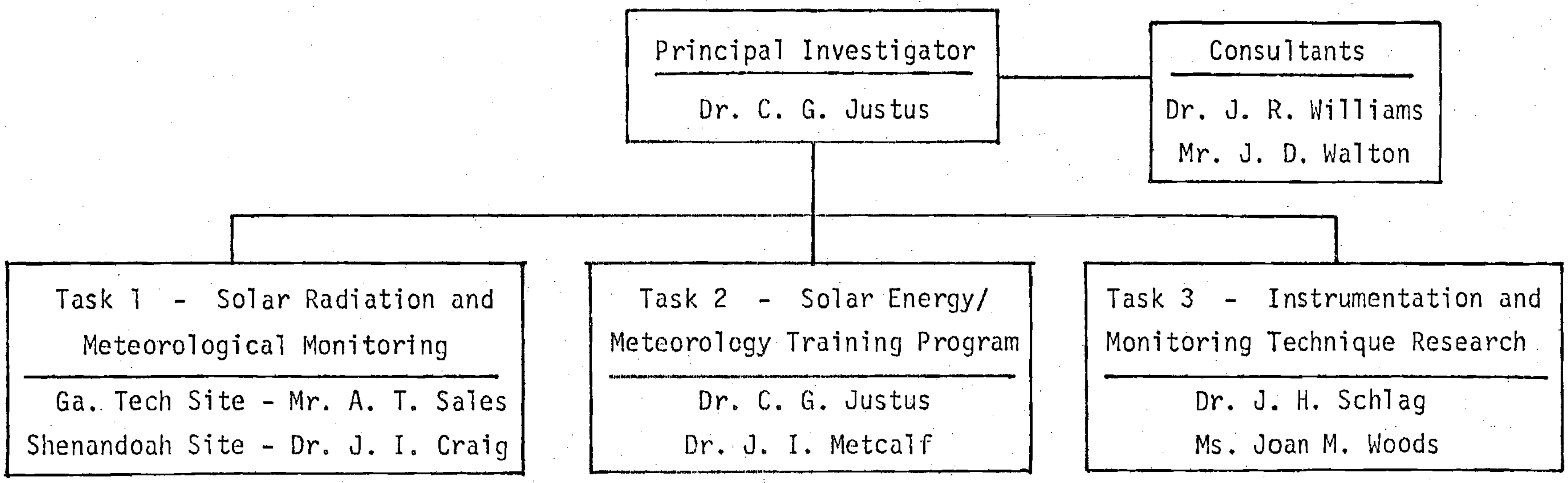


Figure 3.1 - Project Organization Chart

Table 4.1

Instrumentation and Measurements

Solar Energy Meteorology
Research and Training Site
Georgia Tech
Atlanta, GA 30332

A. Basic measurements at fixed site on Georgia Tech Campus

Instrument	Signal Type and Level	No. of Signals	Sample Rate	Remarks
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.*	Unshaded; WG 295 dome
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Unshaded; RG 630 dome
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Shaded; WG 295 dome
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Shaded; RG 630 dome
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Tilted 34°; WG 295 dome
Pyrheliometer (Eppley NIP)	0 to 15 mv DC	1	1 per min.	
Pyrheliometer (Eppley NIP)	0 to 15 mv DC	1	1 per min.	OG 530, RG 630, RG 695 filters
Pyrradiometer (CSIRO)	0 to 50 mv DC	1	1 per min.	Thermopile output
UV Pyranometer (Eppley)	0 to 15 mv DC	1	1 per min	
Thermometer (Rosemount)	0 to 100 mv DC	2	1 per min. each	Tower mounted
Dew Point Sensor (YSI)	0 to 1 V DC	2	1 per min. each	Tower mounted
Pressure Transducer (SA 363)	0 to 5 V DC	1	1 per min.	
Anemometer (Gill; Young)	0 to 5 V DC	2	1 per min. each	Tower mounted
Wind Vane (Gill; Young)	0 to 5 V DC	2	1 per min. each	Tower mounted
Rain Gauge (SA 552)	0 to 5 V DC	1	1 per min.	

* Sample rates are higher but integrated over 1 minute and recorded as 1 minute averages every minute.

Table 4.1 cont'd.

Instrument	Signal Type and Level	No. of Signals	Sample Rate	Remarks
Percent Sunshine (Campbell-Stokes)	NA	NA	1 per hr.	Data reduced manually
Cloud Cover and Current Weather	NA	NA	1 per hr.	Atlanta Airport NWS data

B. Research measurements at fixed site on Georgia Tech Campus

Pyranometer (Spectrolab)	0 to 15 mv DC	1	1 per min.	For comparison with Eppley
Integrating Nephelometer (MRI)	0 - 5 V	1	1 per min.	
Active Cavity Radiometer (TMI)	BCD	1	special studies	Manual operation as calibra tion aid
Turbidity (Volz)	NA	NA	Special Studies	Manual operation
Circumsolar Telescope (LBL)	NA (each scan includes a number of radiation and meteorological parameters)	NA	1 scan per 10 min.	Separate recording, autom operation. Continued oper ion on campus depends on D decisions regarding LBL ci cumsolar program. Filter wheel radiometer instrume on circumsolar telescope c also be used for aerosol l ing and ozone total optica depth determinations.
Spectrometer (Optronics 740 A)	BCD	1	10 per min.	300 to 1070 nm; selectabl size; at 20 nm steps can g spectrum every 4 min. (I budget permits)
Ozone meter (Dasibi)	0 to 1 V DC	1	1 per min.	Operated on campus when n field for other project
Anemometer (MRI 1074)	0 to 5 V	2	1 per min. each	tower mounted, wind turbi
Temperature (thermistor)	0 to 5 V	2	1 per min. each	tower mounted, wind turbi
Humidity (WM-MH111)	0 to 10 V	2	1 per min. each	tower mounted, wind turbi

Table 4.1 cont'd.

Instrument	Signal Type and Level	No. of Signals	Sample Rate	Remarks
Directional Dustfall (WM-APW 1)	NA	NA	Special studies	Gross Particulate measurement
Lidar	NA	NA	1 per min. (Special studies)	Vertical aerosol profiling. Installation and operation by Dr. G. W. Grams depends on separate agency funding of his program. Also gives times of occurrence of thin cirrus for interpretation of circum-solar data.
Polar Nephelometer	NA	NA	1 per 10 min. (special studies)	Dr. G. W. Grams design. Surface or aircraft (Georgia Tech Convair 240) in situ measurements of angular distribution of light scattering from aerosols. Available whe not in use on another project
aerosol size spectrometer, millipore filters, nuclepore filters	NA	NA	1 per min. (spectrometer) 1 per 10 min. (filters) (special studies)	Refractive index versus wave length for aerosols. Size distributions and shapes of aerosols out to very small size range. Available when not in use on another project (Dr. G. W. Grams equipment).

Table 4.1 cont'd.

C. Research measurements at fixed site at Shenandoah (near Newnan, Georgia)

Instrument	Signal Type and Level	No. of Signals	Sample Rate	Remarks
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Unshaded; WG 295 dome
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Unshaded; RG 630 dome
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Shaded; WG 295 dome
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Tilted 34°; WG 295 dome
Pyrheliometer (Eppley NIP)	0 to 15 mv DC	2	1 per min.	Duplicate for redundancy
Pyrheliometer (Eppley NIP)	0 to 15 mv DC	1	1 per min.	WG 295, OG 530, RG 630, F filters
Pyrradiometer (CSIRO)	0 to 50 mv DC	1	1 per min.	Thermopile output
Thermometer		1	1 per min.	New EG & G portable syste
Humidity		1	1 per min.	New EG & G portable syst
Pressure Transducer		1	1 per min.	New EG & G portable syst
Anemometer		1	1 per min.	New EG & G portable syst
Wind Vane		1	1 per min.	New EG & G portable syst
Rain Gauge (SA 552)	0 to 5 V DC	1	1 per min.	
UV Pyranometer (Eppley)	0 to 15 mv DC	1	1 per min.	If budget permits
Nephelometer (MRI)	0 to 5 V	1	1 per min.	If budget permits

Table 4.1 cont'd.

D. Measurements with Portable Monitoring Unit

Instrument	Signal Type and Level	No. of Signals	Sample Rate	Remarks
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Unshaded; WG 295 dome
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Shaded (Shade Ring); WG 295 dome
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Tilted (latitude); WG 295 dome
Pyrheliometer (Eppley NIP)	0 to 15 mv DC	1	1 per min.	WG 295, OG 530, RG 630, RG 695 filters
Thermometer	0 to 100 mv	1	1 per min.	
Dew Point	0 to 1 V	1	1 per min.	
Anemometer	0 to 5 V	1	1 per min.	
Wind Vane	0 to 5 V	1	1 per min.	

Engineering building, about 250 m (820 ft) east of the Solar Thermal Test Facility site (see Figures 4.1 - 4.3). In addition to radiation and meteorological monitoring at the Civil Engineering roof site, meteorological parameters will also be observed with instrumentation on a met tower at the wind turbine test site, adjacent to the Solar Thermal Test Facility (see Figure 4.1).

b. All equipment for the basic and research monitoring have been ordered except the Optronics 740A spectrometer which will be ordered only if the budget permits. Most instruments are scheduled for delivery by May or earlier. Special averaging and calibrating circuits for use with the data logging system have been designed and are now being constructed.

c. The RM Young Gill anemometers have been received, checked out and calibrations checked in the Georgia Tech low turbulence wind tunnel. Instrument check and calibration certification will be done on the other instruments as received.

d. Design of the auxiliary hardware is complete and acquisition of construction materials has begun. All instruments will be mounted on individual pier mounts made from 6.4 cm (2-1/2 inch) telescoping square tubing for individual height adjustability (to avoid mutual interference of instrument horizons). Additional auxiliary hardware items, for which design information has been requested, are an artificial horizon system for the tilted pyranometer and a dew/frost protection ring for pyranometers (Ed Flowers design).

e. Contract arrangements for the campus site (Civil Engineering roof) modifications are being initiated.

f-h. No work in these areas was scheduled during the report quarter.

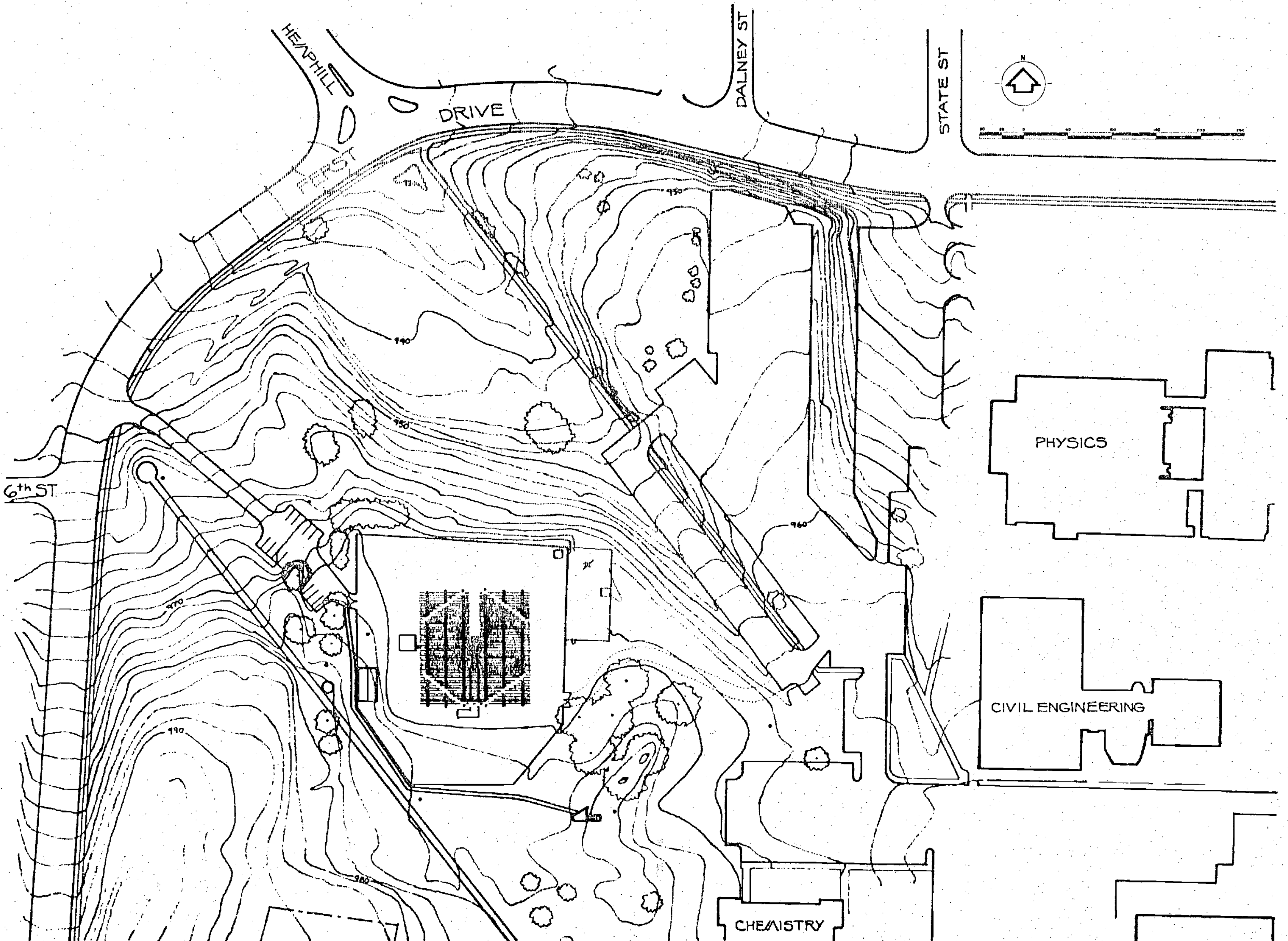


Figure 4.1 - Campus Layout of Georgia Tech Solar Thermal Test Facility, Wind Turbine Test Facility, and Civil Engineering Building Site.

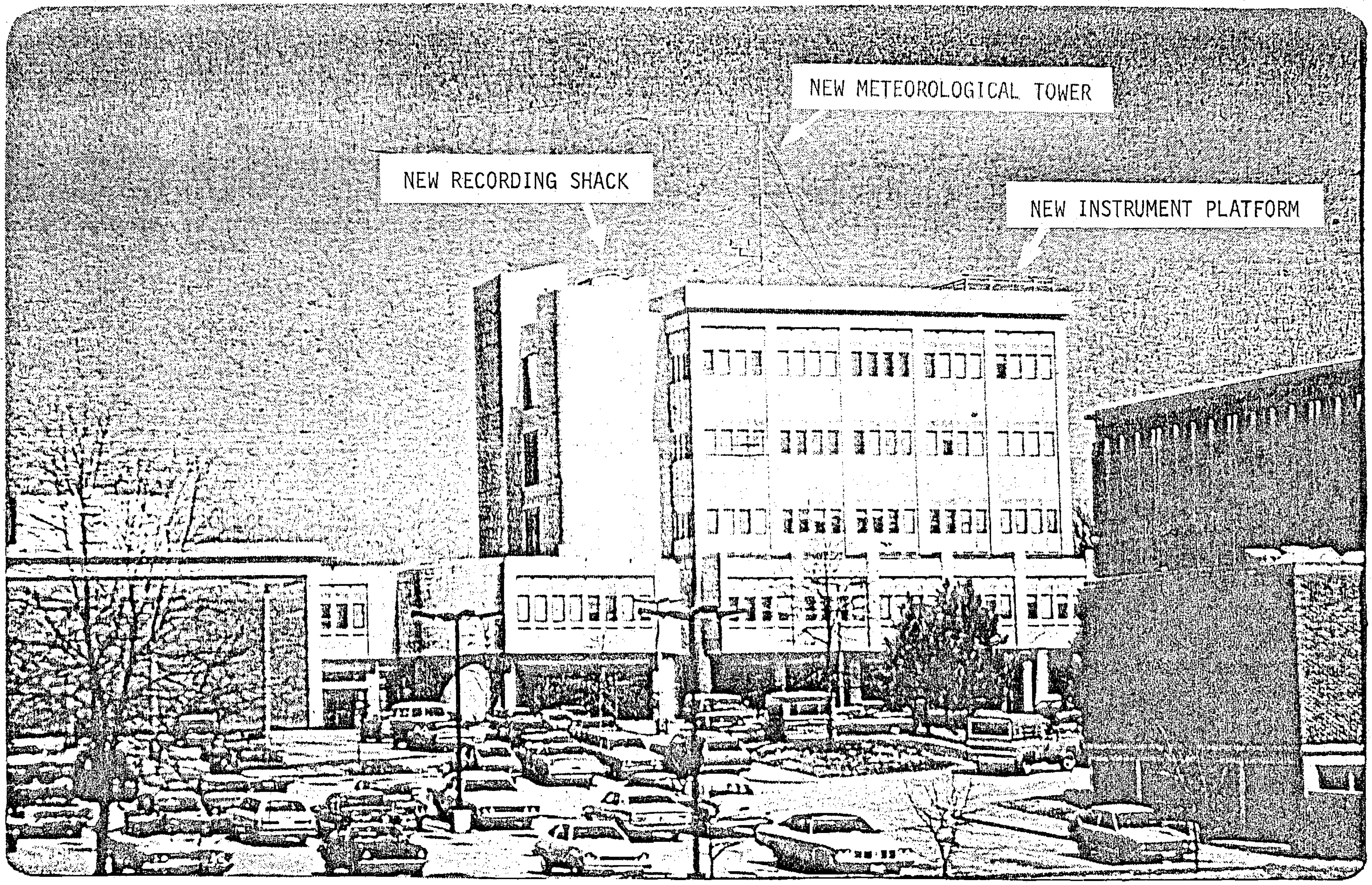


Figure 4.2 - Civil Engineering Building, with artist's view of the added facilities on the roof

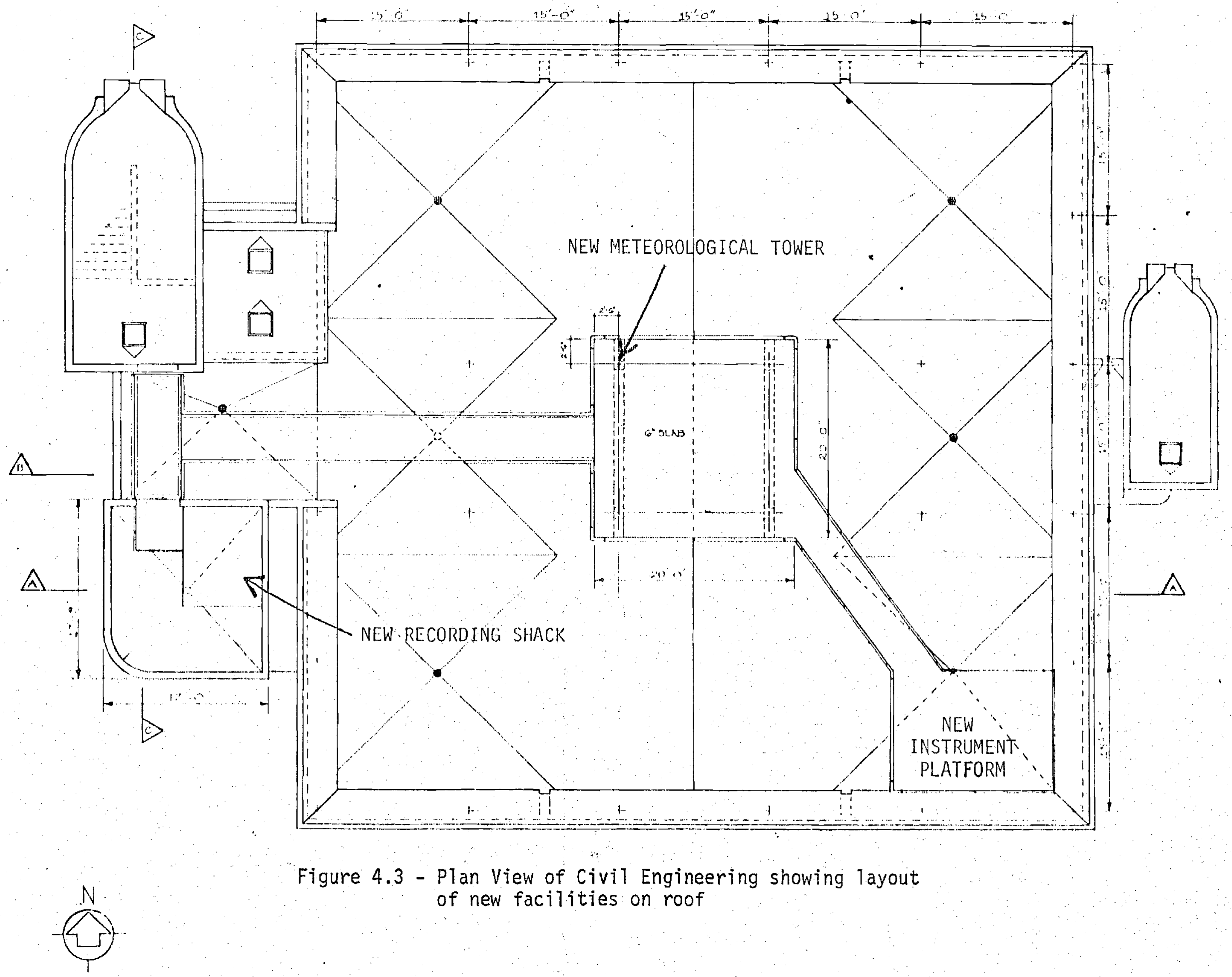


Figure 4.3 - Plan View of Civil Engineering showing layout of new facilities on roof

i. Monitoring at Shenandoah continues with the present EG & G portable monitoring system. A newer version of the EG & G unit is expected to become operational at Shenandoah during the following quarter and additional instruments installed for recording with the expanded capability data logger of the new EG & G unit.

j. Preliminary work and software design has begun on the data acquisition and quality control software.

k-m. No work in these areas was scheduled during the report quarter.

Task 2: Regional Training Program

Approval by the Academic Senate has been received for the new Atmospheric Sciences academic curriculum, summarized in the attachment. Application for the academic program has been made to the Academic Common Market. The Academic Common Market is an interstate agreement among southern states for sharing academic programs. Residents of the participating states who qualify for admission and who are approved by their state coordinators may enroll on an instate tuition basis. The main Geophysical Sciences academic program is already offered on this basis.

Task 3: Instrumentation and Monitoring Techniques Research

The integrating nephelometer, Volz sun photometers have been ordered and received. The directional dustfall sampling equipment has been ordered but not yet received. These will be used to study urban/rural differences in turbidity, visibility, haze/fog, and small and large particulates by comparisons between the urban on-campus site and the rural Shenandoah site. Calibration tests have begun for the nephelometer and Volz photometers.

Summary of Atmospheric Sciences Program

An atmospheric sciences program is being offered leading to the existing degree of Master of Science in Geophysical Sciences [designated] or Master of Science [undesignated].

The Atmospheric Sciences program will consist of three elements:

1) a set of required background undergraduate courses in Geophysical Sciences which cover introductory aspects of the geophysics of the solid earth, the hydrosphere, and the atmosphere, 2) a set of required Atmospheric Science program courses at the graduate level, introducing the three areas of atmospheric dynamics, atmospheric chemistry, and physical meteorology, 3) a set of optional courses whereby a student in the Atmospheric Sciences program may specialize in a track for atmospheric dynamics, atmospheric chemistry, or physical meteorology.

The following Atmospheric Sciences program courses will be offered beginning in September 1978:

Geo. S. 4650	Intro. to Atmospheric Sciences
Geo. S. 6910	Dynamic Meteorology I
Geo. S. 6911	Dynamic Meteorology II
Geo. S. 6791	Atmospheric Turbulence
Geo. S. 6792	Air Pollution Meteorology
Geo. S. 6793	Atmospheric Boundary Layer
Geo. S. 6920	Atmospheric Chemistry I
Geo. S. 6921	Atmospheric Chemistry II
Geo. S. 6930	Physical Meteorology I
Geo. S. 6931	Physical Meteorology II
Geo. S. 6932	Meteorology for Solar and Wind Energy

The required program of study includes required undergraduate background courses, (Geo. S* 2100, 4300, 4650 and either Geo. S. 4500 or 4600) plus Geo. S. 6910, 6911, 6920,6921, 6930, and 6931 plus Geo. S. 7000 Masters Thesis (designated degree) or Geo. S. 8500 Special Problems (undesignated degree).

Members of the faculty who will be major contributors or participants in the program are: Dr. D. D. Davis (Geophys. Sci.), Dr. G. W. Grams (Geophys. Sci.), Dr. C. G. Justus (Geophys. Sci./A.E.), Dr. C. S. Kiang (Geophys. Sci./NCAR), Dr. J. I. Metcalf (EES), and Dr. R. G. Roper (Geophys. Sci./A.E.)

This program has been approved by the Academic Senate and implementation of the new courses will begin in September, 1978.

---

*listed as Geol. XXXX in current catalog

Geo. S. 2100	General Geology
Geo. S. 4300	Introduction to Physical & Chemical Oceanography
Geo. S. 4500	Introduction to Geophysics
Geo. S. 4600	Introduction to Geochemistry

A timing device has been designed for the nephelometer heater which, when ambient humidity exceeds 70%, will cycle between heated (dry particulate only) air and unheated (fog plus dry particulate) air. Tests are being conducted to determine optimum heating cycle.

FORM ERDA 536
(2/1/77)

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

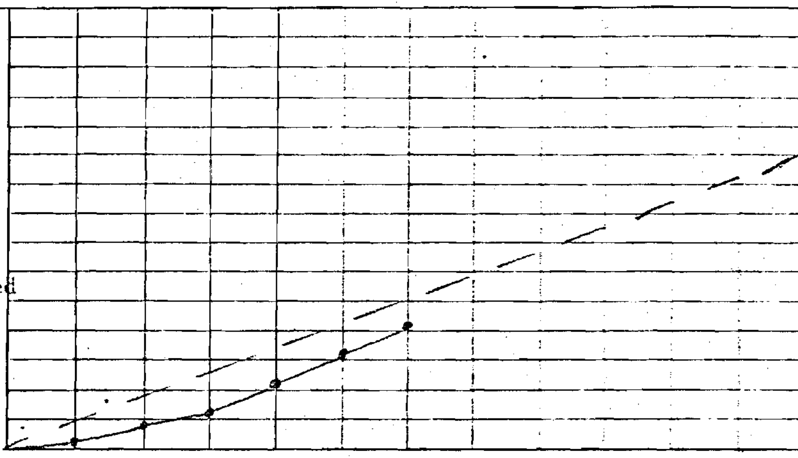
CONTRACT MANAGEMENT SUMMARY REPORT

1. Contract Identification Program for Solar Energy Meteorological Research and Training Site (Region 3)	2. Reporting Period ~~1/1/78~~ through 3/31/78	3. Contract Number EG-77-G-05-5604
4. Contractor (name and address) Georgia Institute of Technology, Atlanta, Georgia 30332		5. Contract Start Date 9/30/77
		6. Contract Completion Date 9/29/78

7. Months	O	N	D	J	F	M	A	M	J	J	A	S	8. FY 78

9. Cost Status

a.



Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S
	b. Planned	17	33	50	67	83	100						
	c. Actual	4	19	25	45	65	85						
	d. Variance	13	14	25	22	18	15						

e. Actual Costs Prior FYs: $ 0

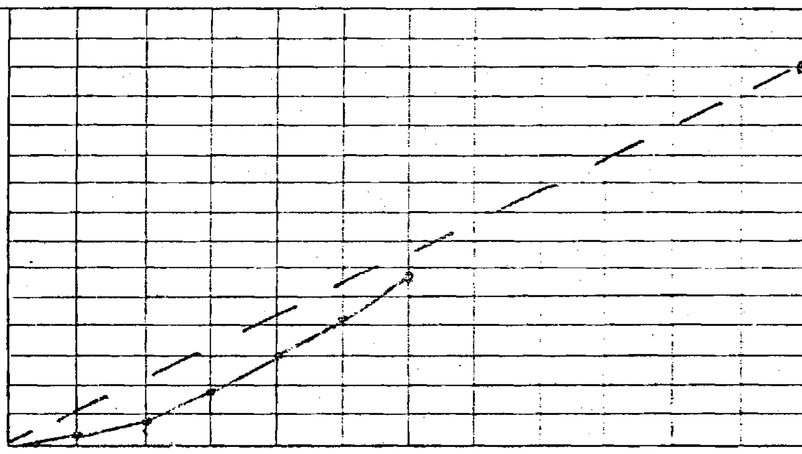
f. Planned Costs Prior FYs: $ 0

g. Total Estimated Accrued Costs for Contract: $ 200,000

h. Total Contract Value: $ 200,000

10. Manpower Status

a.



Manpower		O	N	D	J	F	M	A	M	J	J	A	S
	b. Planned	5	11	16	22	27	33						
	c. Actual	2	4	9	15	21	28						
	d. Variance	3	7	7	7	6	5						

e. Actual Manpower Prior FYs: 0

f. Planned Manpower Prior FYs: 0

g. Total Estimated Manpower for Contract: 65 man months

h. Total Contract Manpower: 65 man months

11. Major Milestone Status

a. See attached Detailed Milestone Chart.

b.

c.

d.

e.

f.

g.

h.

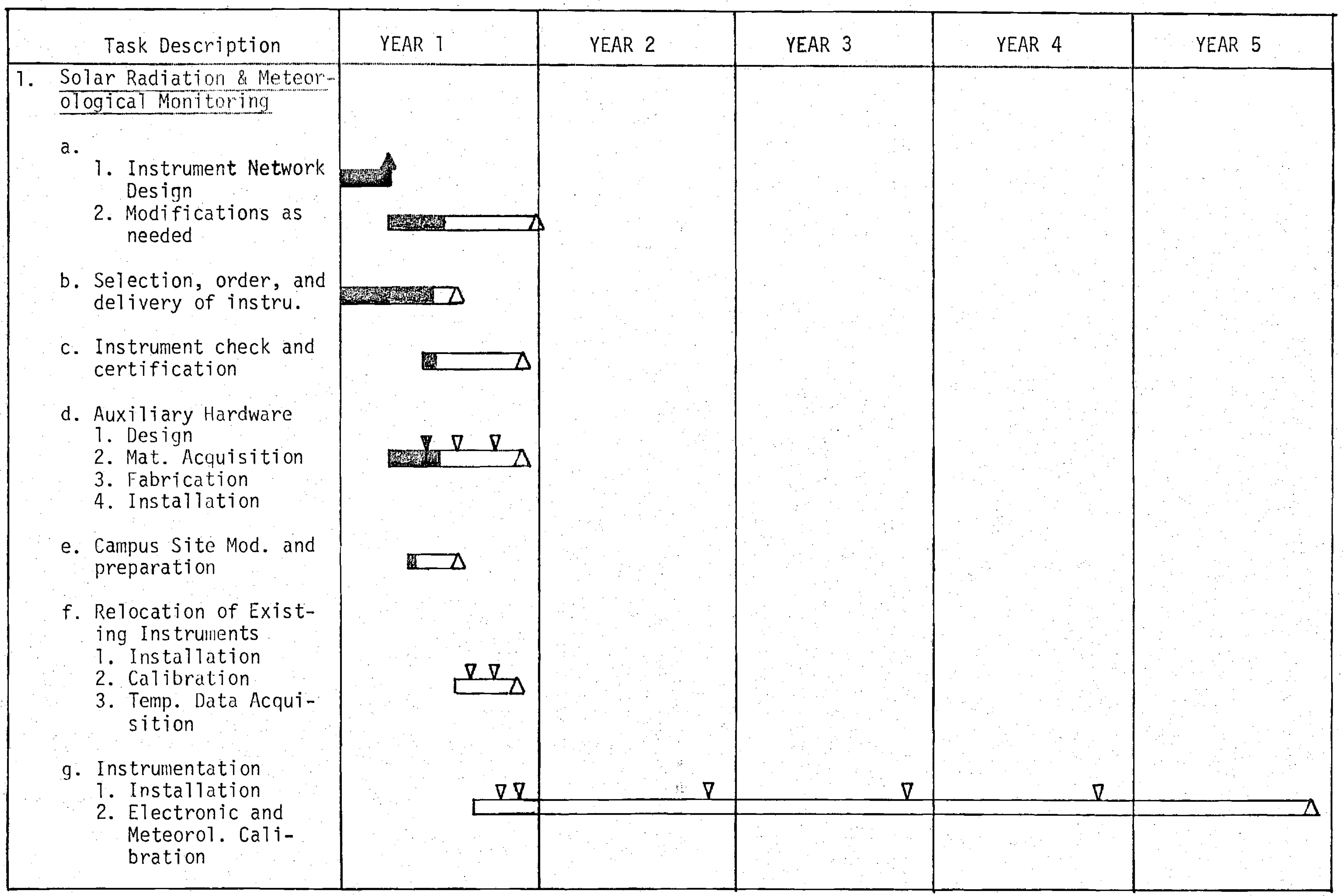
i.

12. Remarks

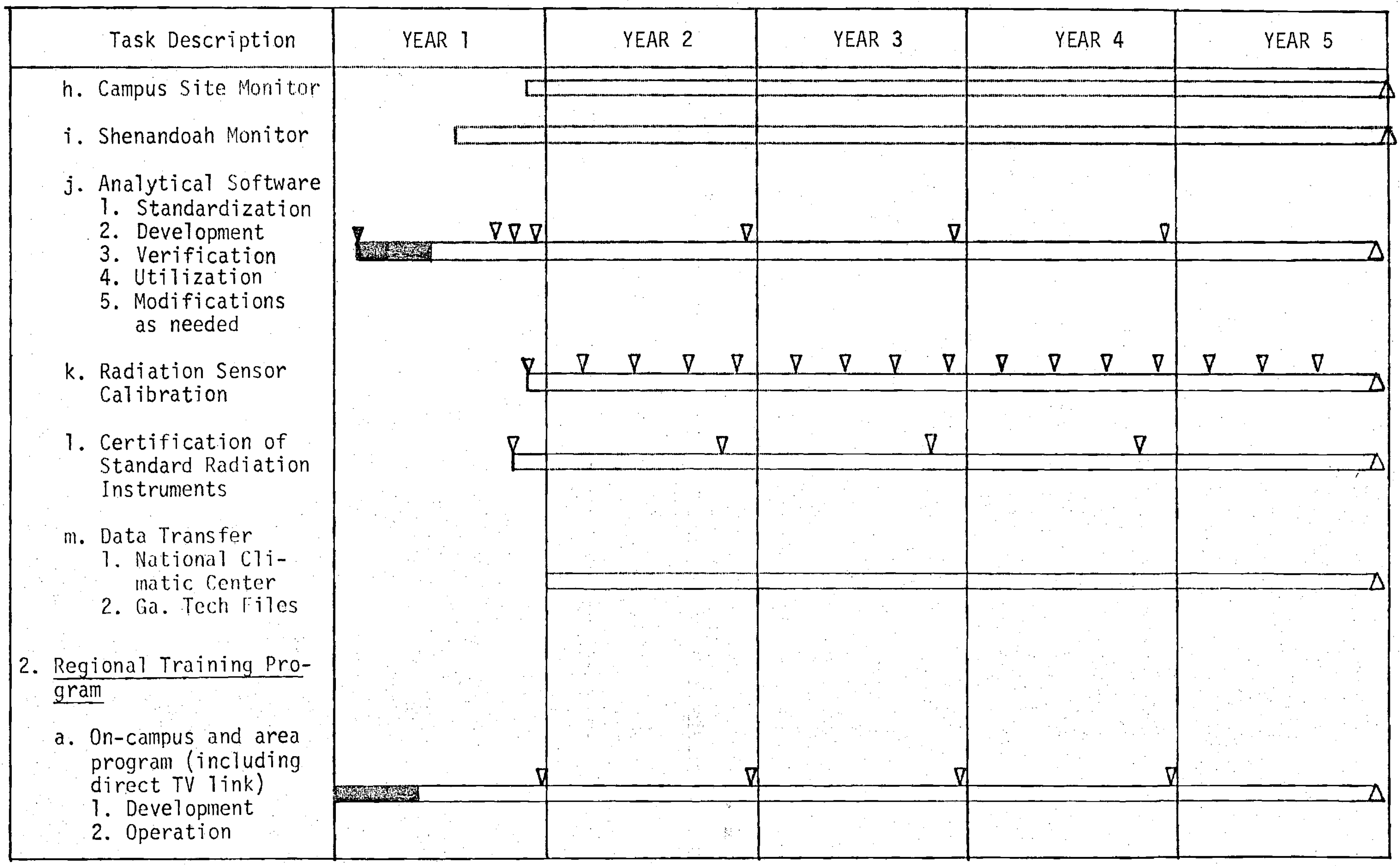
13. Signature of Contractor's Project Manager and Date 5/1/78

14. Signature of Government Technical Representative and Date

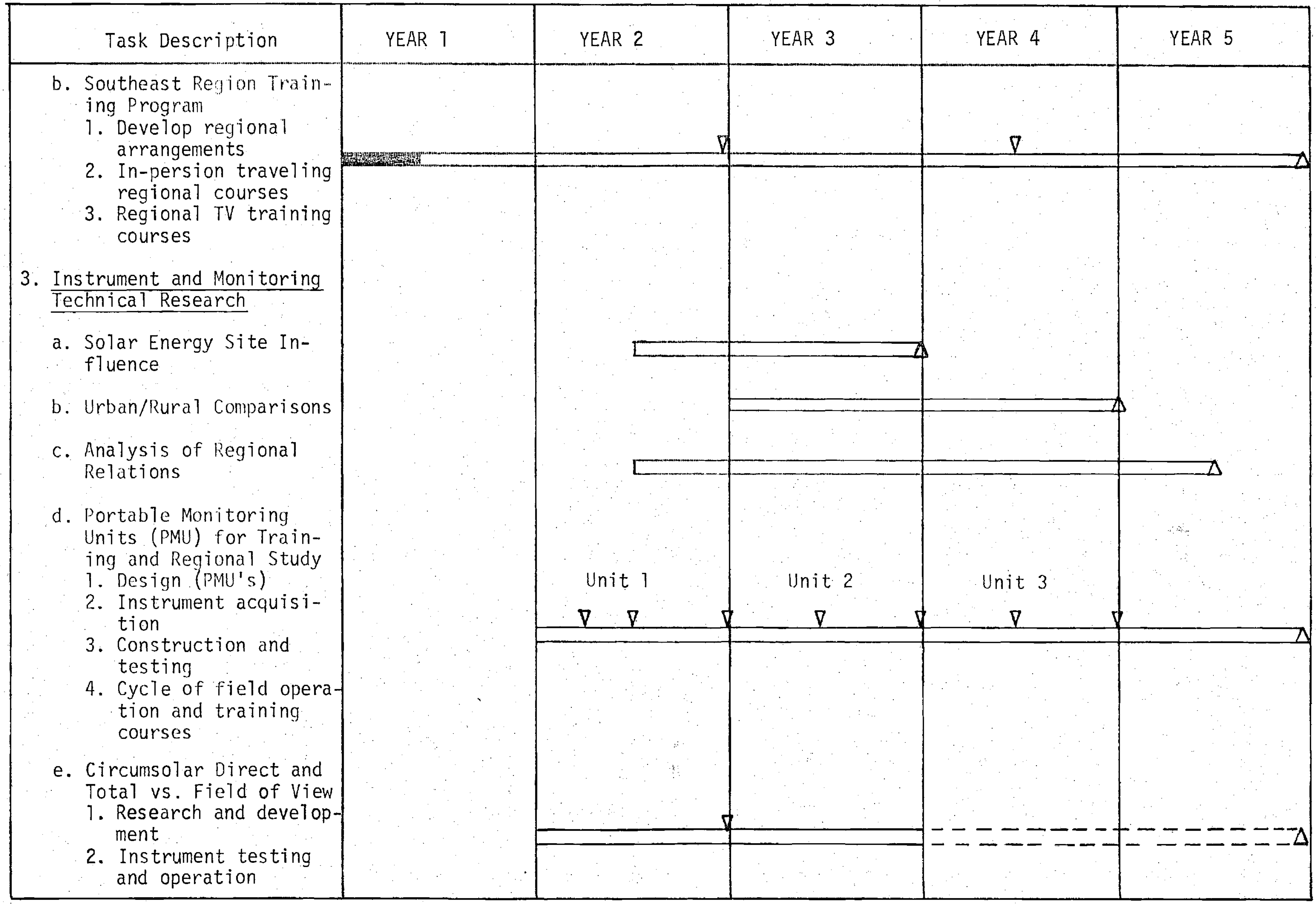
Milestone Chart



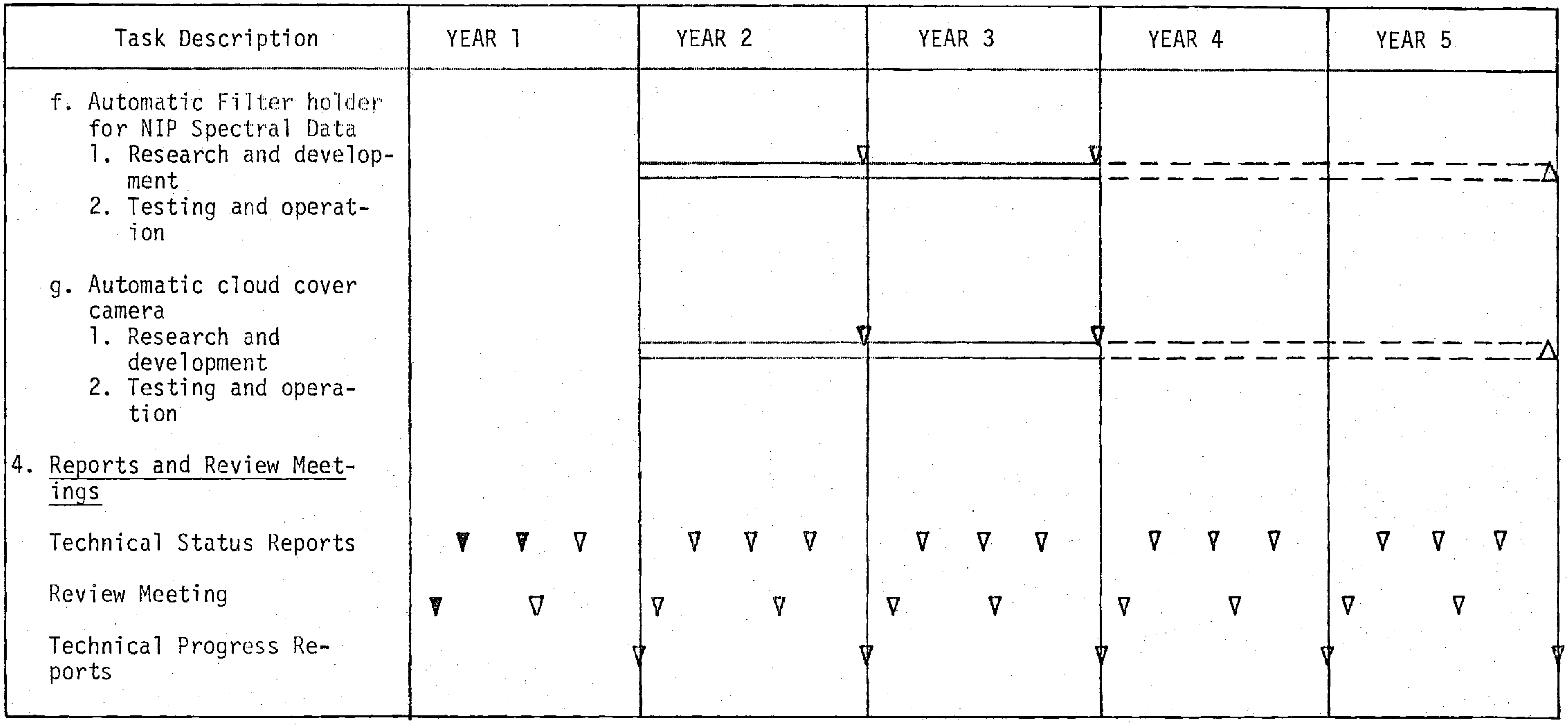
Milestone Chart (Cont'd.)



Milestone Chart (Cont'd)



Milestone Chart (cont'd)



ORO/5604-78/3

PROGRAM FOR SOLAR ENERGY METEOROLOGICAL RESEARCH AND TRAINING SITE (REGION 3)

Quarterly Technical Status and
Contract Management Report

C. G. Justus, Principal Investigator

Georgia Institute of Technology
Atlanta, GA 30332

July, 1978

Report Period April 1, 1978 - June 30, 1978

PREPARED FOR THE UNITED STATES
DEPARTMENT OF ENERGY

DIVISION OF SOLAR ENERGY

UNDER GRANT EG-77-G-05-5604

Georgia Tech Project E-16-630

1. PROJECT OBJECTIVES

This broad program of solar energy and meteorological monitoring, training, and research has the following main objectives for the proposed 5 years duration:

(1) to provide for the Southeast Region (Region 3) a set of continuously monitored and quality controlled data on solar radiation and atmospheric phenomena related to solar energy collection, conversion, and storage, and to relate these to the extensive ongoing solar energy research and engineering projects carried out by Georgia Tech and in the Southeast Region.

(2) by analysis of monitoring results at two sites (on campus, adjacent to the Georgia Tech thermal Test facility and off-campus adjacent to the Shenandoah Solar Total Energy Site), determine: a) optimum siting of solar radiation and meteorological monitoring instruments relative to solar energy systems to provide the most representative site data with the least influence from the solar collector systems, b) adequacy and representativeness for the Southeast Region of various methodologies for relating easily measured phenomena (minutes of sunshine, cloud cover, etc.) to engineering quality solar radiation data (direct, diffus and global insolation, etc.).

(3) to establish and maintain a training program which will allow: a) under graduate and graduate engineering students, through elective or minor courses, to become informed in the areas of meteorology and atmospheric science as they relate to solar and wind energy, b) graduate students in the atmospheric sciences to become informed of the specific requirements of monitoring, analysis, interpretation and presentation of meteor ological information related to engineering aspects of solar and wind

energy, c) professionals in various fields, through short courses and seminars, to become familiar with the new and rapidly developing aspects of solar energy engineering and technology, especially the radiation monitoring and meteorological aspects of this field.

(4) through cooperation in the 3/2 dual degree program, the National Consortium for Graduate Degrees for Minorities in Engineering and other academic programs, enhance the opportunities for minorities (especially Black American and Puerto Ricans) and women in the solar energy engineering and technology field.

(5) instrumentation and monitoring techniques research and development to enhance the engineering applicability of the solar radiation and meteorological monitoring and to provide better instructional tools through low cost instrument systems for educational purposes.

(6) to investigate, with the fixed site instruments and the portable monitoring units (PMU's), the influence of urban haze and aerosols as well as the high levels of natural turbidity which occur in parts of the Southeast region, and with the PMU's to sample the effects on solar radiation of a wide variety of geography (which spans coastal, piedmont plains, and mountainous within the Southeast region).

2. PROJECT PLAN

A. Research Approach and Definition of Tasks

The proposed project plan is divided into three major tasks, each with several subtasks, as follows:

Task 1: Solar Radiation and Meteorological Monitoring Program

This task includes acquisition, initial calibration, and installation of the solar radiation and meteorological instrumentation at the on-campus (Solar Thermal Test Facility/Wind Turbine Test Facility) site and the off-campus (Shenandoah Georgia Solar Total Energy Project) site. Existing and new instrumentation at these sites will be combined and interfaced through data loggers and magnetic tape recording into a form which can be processed, summarized, and formatted by the main campus computer (CYBER 70/74 system). Annual calibration of the instrumentation, against national standards where appropriate, will be carried out, as well as more frequent field calibration of the radiation monitoring instruments. A carefully monitored program of daily instrument inspection and routine maintenance will also be carried out. The detailed outline of the various subtasks under Task 1 is as follows:

a. Based on the proposed variables to be monitored, the Instrumentation Network Design will be laid out using equipment assigned by Georgia Tech for use on this program and additional units to be purchased with the sponsor's approval.

b. Using the preliminary network design, the Selection, Order, and Delivery will be based on recommendations made at the preliminary review meeting of all of the principal investigators.

c. Before an instrument or support unit is put into service, each piece of equipment will be examined and subjected to an Instrument Check and Certification for conformation to Georgia Tech and vendor specifications.

Instruments which fail to pass inspection will be returned to the vendor for replacement.

d. The design, fabrication, and installation of the Auxiliary Hardware which will house and/or support the instrumentation will be according to recommendations in the above articles, of the respective vendors, and to experience gained through use of similar apparatus.

e. Campus Site Modification and Preparation will be done as necessary to accomodate the new monitoring site and instrumentation.

f. The Relocation of Existing Instruments will be performed expeditiously to prevent a loss of data in the present continuous monitoring system. Exposure and operation of the solar radiation and meteorological monitoring instruments will be in accordance with criteria and guidelines published by the WMO(1971) and the IGY (1958).

g. The Instrumentation will be installed and calibrated after it is received and certified.

h. Campus Site Monitoring for the total system is scheduled to begin during the last month of Year 1, but a continuous monitoring system will have been in use for the entire period.

i. The Shenandoah Monitoring System will be used for the entire period after the "Sandia Solar Monitor System" is installed. This basic instrument package will be augmented by additional equipment. Data from the Shenandoah System will be logged on cassette tape. It will then be reformatted and merged with the campus site monitoring data on the CYBER system and put on magnetic tape.

j. Analytical Software will be developed in a standard format which will be used for all research sites. This format was selected at the project directors meeting in Washington, D. C. Data will be taken for analysis

to the CYBER 70/74 computer for transfer to the standard format and storage in this format on magnetic tape, and for transmittal of the raw and summarized data to the National Climatic Center in Asheville.

k. An Instrumentation Calibration by use of a set of special instruments or by techniques specified by the instrument vendor will be performed quarterly to verify instrument accuracy and to establish a permanent record of possible instrument degradation which would affect the acquired data.

l. At the end of each phase of the program, the set of standards would be taken to the Solar Radiation Calibration Facility in Denver, Colorado for Certification of Standard Instruments.

m. The Data Transfer to the National Climatic Center is scheduled to begin on a monthly basis at the end of Year 1 and would continue for the next 48 months. The data will also be stored at Georgia Tech.

Task 2: Solar Energy/Meteorology Training Program

This task involves development and implementation of on-campus, immediat area, and regional training. Existing graduate courses in general meteorology and boundary layer meteorology will be expanded by a new graduate course (open to seniors) in the area of meteorology for solar and wind energy. This course will include training in instrumentation, data acquisition, reduction and analysis. With the formation of an Atmospheric Sciences academic program anticipated to begin in September 1978, this academic curriculum will offer engineers and engineering technologists the opportunity to learn, as a minor or elective course basis, fundamentals of meteorology as it applies to solar energy engineering and technology. It will also allow meteorologists and atmospheric science students in the new program to interact with and learn about the engi-

neering problems and needs related to solar energy technology. This academic program and related short courses for professionals will be made available as appropriate through a unique instructional TV system to become operational at Georgia Tech in September 1978. A "traveling course" to be put on as a short course or a one quarter course at regional colleges will also be implemented. Initially this will be conducted by Georgia Tech personnel. Later, as arrangements are worked out and the local college has personnel trained to proctor or tutor the course, this will be carried via the TV system, either on a video cassette delivery basis, or if the system is developed, via a satellite TV link.

Task 3: Instrumentation and Monitoring Techniques Research

Various research and development aspects related both to the monitoring and the training program, will be carried out under this task. The location of the two monitoring sites - one on-campus within about two miles from the heart of downtown Atlanta, one at the new town Shenandoah site, about 45 miles from Atlanta - will allow evaluation of urban/rural differences, especially related to urban haze and aerosols. The exposure of the instruments adjacent to the Solar Thermal Test Facility and Wind Turbine Test Facility at Georgia Tech will allow evaluation of potential effects on temperature, moisture, and air flow near such facilities. Hence optimum locations will be evaluated for instruments near solar energy facilities, to provide maximum degree of representativeness and minimum influence from the solar energy system on the meteorological measurements. Many models have been proposed in which various meteorological and simply measured radiation parameters (sunshine hours, temperature, cloud cover, solar declination, etc.) can be used to estimate engineering quality insolation (global and direct insolation, global on inclined surfaces, etc.). Some of these methods are those of Fritz (1957), Angstrom (1956), Black et al (1954), Glover and McCulloch (1958), Sabbagh et al (1977), Liu and Jordan (1960),

Whillier (1956) Bennett (1965), Swartman and Ogunladeo (1967), Reddy (1971a, 1971b), Norris (1966), Masson (1966), Atwater (1974), Lumb (1964), L'Vova (1972) Machta (1974), Paltridge (1974), Lin (1973), and Randall et al (1977). Through NOAA (Machta, private communication) a set of linear regression coefficients is being developed for the 26 rehabilitated solar radiation data stations. Using this model, the National Climatic Center will prepare, by November 1977, solar radiation estimates for 200 stations in the U.S. These data will be put on magnetic tape in SOLMET format. The data from the on-campus and off-campus monitoring sites as well as from the 5 Southeastern sites in the new 35 site NOAA network (Riches, 1975) will be used to study regional relationships between simply monitored parameters and solar radiation data for engineering purposes. Results of the contract study resulting from the recent RFP to Perform a Solar Radiation Data Forecast and Interpolation Analysis will also be applied in this study. Emphasis will be on study of the influence of turbidity (high in parts of the Southeast region), and regional geography (which spans coastal, piedmont plains, and mountain areas). During the second and subsequent years up to three low cost portable monitoring units will be designed and built. These units will be used in the training program as instructional systems for the traveling course to regional colleges. Data from these units will also be used in the analysis of methods to relate simple measured parameters to engineering quality insolation data for the region. Other instrument and monitoring techniques for which research and development projects are envisioned will include:

a. an automatic filter changing wheel for the normal incidence pyrheliometer (to automatically switch on a 1/minute or less basis between clear, OG1, RG2, and RG8 filters),
b. circumsolar radiation with the Lawrence Berkley Labs circumsolar telescope, currently on campus and projected to remain here throughout at least a portion of this project, and

c. an automatic wide field of view camera system to provide a film record of cloud cover conditions.

3. ADMINISTRATIVE STATUS

No changes. Project team and organization is as shown in Figure 3.1. Joan Wood has returned from maternity leave. A project sub budget has been established with Dr. George Fletcher of the Engineering Experiment Station Systems Engineering Division. He and members of that Division will assist in the data quality control and processing activities.

4. PROGRESS TO DATE

Task 1: Solar Radiation and Meteorological Monitoring Program

a. Instrumentation for the parameters to be monitored is outlined in Table 4.1. The instrumentation network design was completed during the previous quarter. No modifications have been required as yet.

b. Additional items delivered during the quarter are the PSP's, NIP's and tracking units, activity cavity radiometer, UV radiometer, and filters for spectral measurements. Items yet to be delivered include the tracking disk system for diffuse radiation, CSIRO pyrradiometer, temperature, humidity and pressure transducers, and rain gage. These items should be delivered within the next month to six weeks.

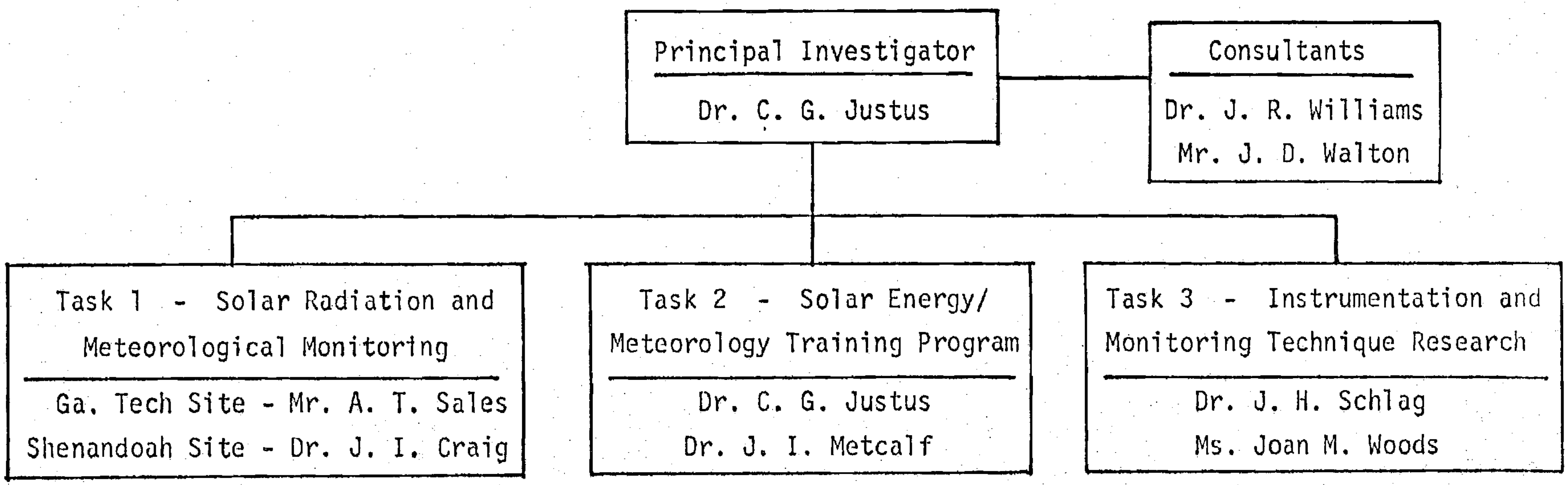


Figure 3.1 - Project Organization Chart

Table 4.1

Instrumentation and Measurements

Solar Energy Meteorology
Research and Training Site
Georgia Tech
Atlanta, GA 30332

A. Basic measurements at fixed site on Georgia Tech Campus

Instrument	Signal Type and Level	No. of Signals	Sample Rate	Remarks
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.*	Unshaded; WG 295 dome Global
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Unshaded; RG 630 dome Global spectral
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Shaded; WG 295 dome Diffuse
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Shaded; RG 630 dome Diffuse spectral
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Tilted 34°; WG 295 dome Global tilted
Pyrheliometer (Eppley NIP)	0 to 15 mv DC	1	1 per min.	Direct
Pyrheliometer (Eppley NIP)	0 to 15 mv DC	1	1 per min.	OG 530, RG 630, RG 695 filters Direct spectral
Pyrradiometer (CSIRO)	0 to 50 mv DC	1	1 per min.	Thermopile output Total
UV Pyranometer (Eppley)	0 to 15 mv DC	1	1 per min	UV
Thermometer (Rosemount)	0 to 100 mv DC	2	1 per min. each	Tower mounted, temperature and ΔT
Dew Point Sensor (YSI)	0 to 1 V DC	2	1 per min. each	Tower mounted, 2 levels
Pressure Transducer (SA 363)	0 to 5 V DC	1	1 per min.	
Anemometer (Gill; Young)	0 to 5 V DC	2	1 per min. each	Tower mounted, propeller vane
Wind Vane (Gill; Young)	0 to 5 V DC	2	1 per min. each	Tower mounted, propeller vane
Rain Gauge (SA 552)	0 to 5 V DC	1	1 per min.	

* Sample rates are higher but integrated over 1 minute and recorded as 1 minute averages every minute.

Table 4.1 cont'd.

Instrument	Signal Type and Level	No. of Signals	Sample Rate	Remarks
Percent Sunshine (Campbell-Stokes)	NA	NA	1 per hr.	Data reduced manually
Cloud Cover and Current Weather	NA	NA	1 per hr.	Atlanta Airport NWS data

B. Research measurements at fixed site on Georgia Tech Campus

Pyranometer (Spectrolab)	0 to 15 mv DC	1	1 per min.	For comparison with Epple
Integrating Nephelometer (MRI)	0 - 5 V	1	1 per min.	
Active Cavity Radiometer (TMI)	0 - 5 V	1	special studies	Manual operation as calib tion aid
Turbidity (Volz)	NA	NA	Special Studies	Manual operation
Circumsolar Telescope (LBL)	NA (each scan includes a number of radiation and meteorological parameters)	NA	1 scan per 10 min.	Separate recording, aut operation. Continued op ion on campus depends on decisions regarding LBL cumsolar program. Filte wheel radiometer instru on circumsolar telescope also be used for aerosol ing and ozone total opti depth determinations.
Spectrometer (Optronics 740 A)	BCD	1	10 per min.	300 to 1070 nm; selectab size; at 20 nm steps car spectrum every 4 min. budget permits)
Ozone meter (Dasibi)	0 to 1 V DC	1	1 per min.	Operated on campus when field for other project
Anemometer (MRI 1074)	0 to 5 V	2	1 per min. each	tower mounted, wind tur
Temperature (thermistor)	0 to 5 V	2	1 per min. each	tower mounted, wind tur
Humidity (WM-MH111)	0 to 10 V	2	1 per min. each	tower mounted, wind tur

Table 4.1 cont'd.

Instrument	Signal Type and Level	No. of Signals	Sample Rate	Remarks
Directional Dustfall (WM-APW 1)	NA	NA	Special studies	Gross Particulate measurements
Lidar	NA	NA	1 per min. (Special studies)	Vertical aerosol profiling. Installation and operation by Dr. G. W. Grams depends on separate agency funding of his program. Also gives times of occurrence of thin cirrus for interpretation of circum-solar data.
Polar Nephelometer	NA	NA	1 per 10 min. (special studies)	Dr. G. W. Grams design. Surface or aircraft (Georgia Tech Convair 240) in situ measurements of angular distribution of light scattering from aerosols. Available when not in use on another project.
aerosol size spectrometer, millipore filters, nuclepore filters	NA	NA	1 per min. (spectrometer) 1 per 10 min. (filters) (special studies)	Refractive index versus wave length for aerosols. Size distributions and shapes of aerosols out to very small size range. Available when not in use on another project (Dr. G. W. Grams equipment).

Table 4.1 cont'd.

C. Research measurements at fixed site at Shenandoah (near Newnan, Georgia)

Instrument	Signal Type and Level	No. of Signals	Sample Rate	Remarks
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Unshaded; WG 295 dome
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Unshaded; RG 630 dome
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Shaded; WG 295 dome
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Tilted 34°; WG 295 dome
Pyrheliometer (Eppley NIP)	0 to 15 mv DC	2	1 per min.	Duplicate for redundanc
Pyrheliometer (Eppley NIP)	0 to 15 mv DC	1	1 per min.	WG 295, OG 530, RG 630, filters
Pyrradiometer (CSIRO)	0 to 50 mv DC	1	1 per min.	Thermopile output
Thermometer		1	1 per min.	New EG & G portable sys
Humidity		1	1 per min.	New EG & G portable sys
Pressure Transducer		1	1 per min.	New EG & G portable sys
Anemometer		1	1 per min.	New EG & G portable sys
Wind Vane		1	1 per min.	New EG & G portable sys
Rain Gauge (SA 552)	0 to 5 V DC	1	1 per min.	
UV Pyranometer (Eppley)	0 to 15 mv DC	1	1 per min.	If budget permits
Nephelometer (MRI)	0 to 5 V	1	1 per min.	If budget permits

Table 4.1 cont'd.

D. Measurements with Portable Monitoring Unit

Instrument	Signal Type and Level	No. of Signals	Sample Rate	Remarks
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Unshaded; WG 295 dome
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Shaded (Shade Ring); WG 295 dome
Pyranometer (Eppley PSP)	0 to 15 mv DC	1	1 per min.	Tilted (latitude); WG 295 dome
Pyrheliometer (Eppley NIP)	0 to 15 mv DC	1	1 per min.	WG 295, OG 530, RG 630, RG 695 filters
Thermometer	0 to 100 mv	1	1 per min.	
Dew Point	0 to 1 V	1	1 per min.	
Anemometer	0 to 5 V	1	1 per min.	
Wind Vane	0 to 5 V	1	1 per min.	

c. Preliminary calibrations have been done on the NIP's using the Active Cavity Radiometer as reference. Results are summarized in Table 4.2. NIP 17004E6 was selected as the secondary standard unit, because of the close agreement of its measured and laboratory calibration values. NIP's 13656E6 and 5266 in Table 4.2 are units in use on other Georgia Tech projects which were calibrated at the same time. Both of these units had factory calibrations relative to IPS 1956 rather than the Absolute Scale 1977. Thus deviations of measured calibrations from factory calibrations would be raised (reduced in magnitude) 2.1% to account for the shift to Absolute Scale. PSP's and the Spectrolab SR75 were calibrated by two methods: 1) sun/shade measurements equating the direct beam removed to the direct radiation measured by the Active Cavity Radiometer, and 2) calibration transfer from PSP 17063F3 which showed values from the sun/shade calibration consistent with its factory calibration. Three PSP's and one 8-48 in use on other Georgia Tech projects were also calibrated at the same time. Results of these calibrations are presented in Table 4.3. In general the calibration transfer results fall in between the factory calibration values and the sun/shade results. The sun/shade and calibration transfer results agree within an rms difference of 1.0%. Instrument check and certification on all units on hand is complete. Check and certification of equipment yet to be received will be done as soon as possible after arrival.

Table 4.2

NIP Calibration Results

Wire Code	Instr. Type	Serial No.	Factory Cal $\mu V/Wm^{-2}$	ACR Calibration avg.	ACR Calibration σ	ACR Calibration σ%	Deviation from Factory Cal %
33	NIP	17008E6	6.64	6.84	0.03	0.5	3.0
34	NIP	17004E6	8.52	8.59	0.02	0.2	0.8
35	NIP	16995E6	7.65	7.75	0.03	0.4	1.3
36	NIP	17003E6	6.76	6.89	0.02	0.2	1.9
32	NIP	13656E6	7.74	7.54	0.03	0.3	-2.6
43	NIP	5266	7.48	7.14	0.01	0.1	-4.6

TABLE 4.3

PSP Calibration Results

Wire Code	Instr. Type	Serial No.	Factory Cal $\mu V/Wm^{-2}$	Sun/Shade Cal $\mu V/Wm^{-2}$ avg.	σ	σ%	Deviation from Factory Cal, %	Global Ref. to #25 $\mu V/Wm^{-2}$ avg.	σ	σ%	Deviation from Factory Cal. %	Deviation from Sun/Shade %
23	PSP	17061F3	9.79	9.67	0.12	1.3	-1.2	9.73	0.01	0.1	-0.6	0.6
24	PSP	17059F3	9.67	9.45	0.05	0.5	-2.3	9.51	0.04	0.4	-1.7	0.6
25	PSP	17063F3	9.82	9.79	0.10	1.0	-0.3	9.80	(assumed value)			
26	PSP	17060F3	9.53	9.34	0.19	2.0	-2.0	9.45	0.01	0.1	-0.8	1.2
27	PSP	17065F3	9.16	9.01	0.11	1.2	-1.6	9.11	0.02	0.2	-0.5	1.1
28	PSP	17064F3	9.57	9.50	0.12	1.3	-0.7	9.57	0.02	0.2	0.0	0.7
29	PSP	17066F3	9.63	9.40	0.02	0.2	-2.4	9.55	0.01	0.1	-0.8	1.6
30	PSP	17062F3	9.73	9.64	0.03	0.3	-0.9	9.75	0.05	0.5	0.2	1.1
31	SR75	77120	10.44	9.91	0.04	0.4	-5.1	9.97	0.01	0.1	-4.5	0.6
37	PSP	15092F3	9.47	9.23	0.05	0.5	-2.5	9.33	0.02	0.2	-1.5	1.1
38	PSP	15224F3	9.50	9.17	0.07	0.8	-3.5	9.28	0.03	0.3	-2.3	1.2
39	PSP	16684F3	9.54	9.39	0.09	1.0	-1.6	9.45	0.04	0.4	-0.9	0.6
42	8-48	15057	11.23	10.85	0.24	2.2	-3.4	11.25	0.13	1.1	0.2	3.7

d. Metal plates for the tops of the mounting piers have been received and cut to size. Delivery of the telescoping tubing is still awaited. A mounting box for the amplifiers for the PSP's and NIP's will be acquired or fabricated.

e. The contract has been let for installation of the roof pad, recording shack and meteorological tower on the roof of the Civil Engineering building. Completion of this installation is anticipated before September 1, 1978.

f. The original plan called for relocation of a NIP, a PSP and some meteorological equipment from the Advanced Components Test Facility site to the adjacent solar radiation monitoring facility. Since the monitoring site will now be some distance away (about 250 m), on the roof of Civil Engineering, these instruments will not be relocated. Instead they will continue to be used in continuous monitoring (strip chart recording) at the Advanced Components Test Facility Site.

g. Instrumentation was temporarily installed on the roof of the Hinman Research Building for calibration tests. Installation at the permanent site awaits completion of the Civil Engineering rooftop facilities.

h. No work was scheduled in this area during this quarter.

i. The 8 channel Shenandoah monitoring system continues in operation. Cassettes are being sent directly to EG & G for data reduction. The 16 channel system is expected to be sent by EG & G in August. The additional instruments will be added soon after that and the extended monitoring will begin.

j. A program to calculate direct, diffuse, and global radiation at any time of the day and year has been written. The techniques employed in the program are those documented by Watt Engineering in their recent report (HCP/T2552-01). It is anticipated that this program will be used as an integral part of the quality control analysis of the monitored data.

k-l. Instrument calibration activities were described above. Secondary standard NIP and PSP units have been sent to Ed Flowers for calibration. The secondary standard NIP will be compared against the active cavity radiometer when it is returned. Calibration of the secondary standard PSP will be transferred to the other PSP units via additional simultaneous monitoring.

m. No work was scheduled in this area during this quarter.

Task 2: Solar Energy/Meteorology Training Program

The new Atmospheric Sciences program, discussed in the previous quarterly report, was proposed to the Academic Common Market. The Academic Common Market is an interstate agreement among southern states for sharing academic programs. Residents of the participating states who qualify for admission and who are approved by their state coordinators may enroll on an instate tuition basis. There are 13 participating states in the Academic Common Market. Of the 12 others besides Georgia, 7 have elected to participate cooperatively in the Georgia Tech Atmospheric Sciences program (Alabama, Kentucky, Louisiana, South Carolina, Tennessee, Virginia, and West Virginia).

Initial contacts have been made with the Atlanta University Center about the establishment of a dual degree program in the atmospheric sciences area.

The Atlanta University Center is a group of traditionally black colleges in the metropolitan Atlanta area. The dual degree program allows students to attend another school, then come to Georgia Tech and receive a degree from both institutes. For example, in the 3/2 dual degree B.S. program a student would attend the other school for 3 years, Georgia Tech for 2, then receive a degree (usually liberal arts oriented) from his original institute <u>and</u> a degree (usually science or engineering) from Georgia Tech. The list of participating colleges with which Georgia Tech is already affiliated in the dual degree program includes 10 traditionally black colleges as well as 20 predominantly women's colleges.

A short course on Solar Radiation Measurement and Application will be offered in October. Description of this course is attached. Discussions have been held with the Center for Media Based Education about the possibilities of TV cassette recording of this short course for offering around the region. The new graduate course Meteorology for Solar and Wind Energy, described in the last quarterly report, will be offered in the Winter quarter. Discussions were also held about the possibility of TV cassette recording of that course.

A letter is being drafted for distribution to other colleges and to businesses within the Southeast Region soliciting ideas for mutual cooperative efforts in the monitoring and training area.

<u>Task 3: Instrumentation and Monitoring Techniques Research</u>

Both Volz photometers have now been received and intercomparison tests have been run. These showed differences of about 0.1 in τ_e (500 nm), about 0.05 in τ_e (380 nm) and 0.01 in τ_e (880 nm). Precipitable water estimates differed about 1.5 cm between the two units. Additional tests will be done on intercomparison.

The integrating nephelometer has been tested with a cycle timer on the heater. When the relative humidity exceeds a certain level (now at 70%) the heater can be cycled on and off (now set for 20 minutes on, 40 minutes off). This will allow measurements of dry particulate and fog particles at high humidity levels. The humidity of the outflowing air will also be monitored as part of the nephelometer studies.

SHORT COURSE DESCRIPTION

TITLE: SOLAR RADIATION MEASUREMENT AND APPLICATIONS

Precise solar radiation information is required for accurate performance evaluation of solar energy systems. Global radiation on tilted surfaces is required for flat plate collectors. Direct beam and circumsolar radiation information are needed for focusing collectors. For solar cooling applications, radiative transfer information on infra-red radiation is required.

In many cases available solar radiation data are unsuitable as measured. For example, direct beam data have been measured for long periods at only a very few locations. Often only global radiation data on a horizontal surface are available.

This course is designed to familiarize the participant with the methods for measuring and utilizing solar radiation information. It will illustrate when and how existing solar radiation data bases may be used in certain engineering applications. For monitoring of insolation, the course covers various aspects of monitoring instrumentation, installation, operation, calibration, data acquisition, and processing.

COURSE TOPICS

<u>Solar Radiation Characteristics</u>. Descriptive aspects. The solar constant. Solar radiation at the earth's surface.

<u>The terrestrial atmosphere</u>. Effects on intensity and directional characteristics of radiation. Molecular and aerosol absorption and scattering. Effects of clouds.

<u>Measurements of solar radiation parameters</u>. Average values and fluctuations. Geographical and seasonal effects.

Instrumentation. Types of instruments. Installation, operation, and calibration. Data acquisition and quality control.

Available Solar Radiation Data. Survey of available insolation data, its acquisition and applications.

Applications. Use of solar radiation data in design of energy conversion systems and solar homes and buildings.

FACULTY

Dr. C. G. Justus, Dr. J. R. Williams and Dr. A. P. Sheppard are the academic administrators for the course. Dr. Justus is a professor in the Atmospheric Sciences Program of the School of Geophysical Sciences. He is the principal investigator of the D.O.E. sponsored Solar Energy Meteorological Research and Training Site program at Georgia Tech. Under this project instrumentation is being installed to measure a wide variety of solar radiation and related meteorological data. A continuous, well calibrated and quality controlled set of instrumentation will continue the monitoring, which will produce an extended period of research-grade solar radiation information for solar energy purposes.

Dr. Williams is associate dean of the College of Engineering and professor of mechanical engineering. He is author of Solar Energy Technology and Applications, Ann Arbor Science, 1974 and 1977, and is principal investigator of six D.O.E. sponsored research projects, including the design and construction of what is now the world's largest solar heated and air conditioned building and several other heating and cooling projects, and has responsibility for three Georgia Tech contracts on solar concentrators. He is also responsible for Georgia Tech's participation in two large solar total energy demonstration projects.

Dr. Sheppard is associate vice-president for research at Georgia Tech and professor of electrical engineering. He has served as coordinator of the many solar energy research projects at Georgia Tech and has spent some time at the CNRS Solar Furnace at Odeillo, France and is involved in solar energy applications to agriculture.

Other faculty participants, with their areas of interest, include the following:

Mr. Eugene A. Carter, Research Associate, Center for Environmental and Energy Studies, University of Alabama at Huntsville, solar radiation monitoring network design and implementation,

Mr. David L. Christensen, Research Associate, Center for Environmental and Energy Studies, University of Alabama at Huntsville, solar radiation instrumentation and applications,

Dr. G. W. Grams, Professor, School of Geophysical Sciences, Georgia Tech, physical principles of solar radiation and its transport through the atmosphere,

Dr. J. I. Craig, Associate Professor, Aerospace Engineering, Georgia Tech, solar instrumentation and environmental evaluation and design applications,

Dr. J. H. Schlag, Associate Professor, Electrical Engineering, Georgia Tech, solar tracking, recording and processing instrumentation,

Dr. J. I. Metcalf, Senior Research Scientist, Engineering Experiment Station, Georgia Tech, solar radiation transport, atmospheric effects.

TOUR OF FACILITIES

A tour will be provided of the Solar Energy Meteorological Research and Training Site, the circumsolar radiation facility, and the remote monitoring site at Shenandoah. These facilities include instrumentation for measurement of global, direct, and diffuse radiation, global on a tilted surface, global and diffuse spectral radiation, UV, IR, atmospheric turbidity, and many associated meteorological parameters.

FORM ERDA 536
(2/1/77)

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

CONTRACT MANAGEMENT SUMMARY REPORT

1. Contract Identification Program for Solar Energy Meteorological Research and Training Site (Region 3)	2. Reporting Period 4/1/78 through 6/30/78	3. Contract Number EG-77-G-05-5604
4. Contractor (name and address) Georgia Institute of Technology Atlanta, Georgia 30332		5. Contract Start Date 9/30/77
		6. Contract Completion Date 9/29/78

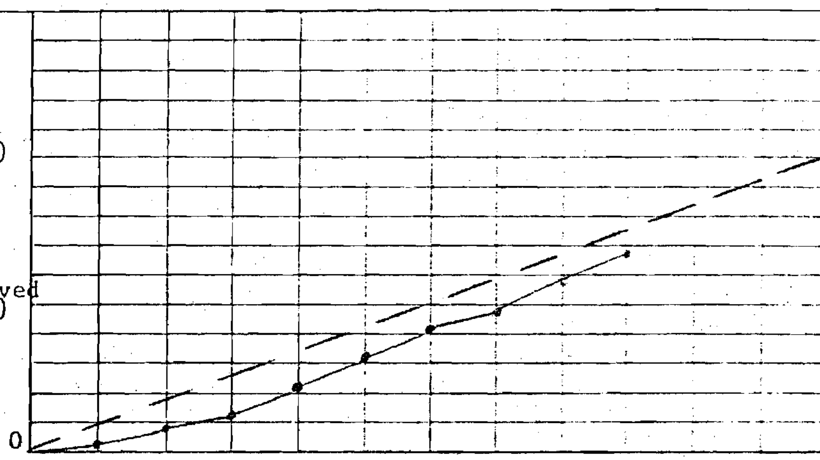
7. Months	O	N	D	J	F	M	A	M	J	J	A	S	8. FY 78

9. Cost Status

a.

Dollars x 1000

Legend:
--------Planned & Approved
________Actual
-.-.-.-.-Contractors Latest Estimate



Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S
b. Planned	17	33	50	67	83	100	117	133	150			
c. Actual	4	19	25	45	65	85	96	118	135			
d. Variance	13	14	25	22	18	15	21	15	15			

e. Actual Costs Prior FYs $ 0

f. Planned Costs Prior FYs $ 0

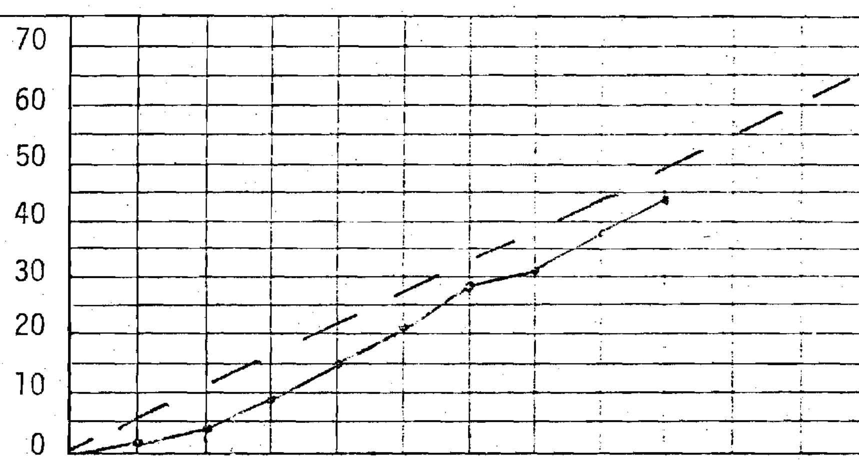
g. Total Estimated Accrued Costs for Contract $ 200,000

h. Total Contract Value $ 200,000

10. Manpower Status

a.

Months
Man ~~Hours~~ x 1



Manpower	O	N	D	J	F	M	A	M	J	J	A	S
b. Planned	5	11	16	22	27	33	38	43	49			
c. Actual	2	4	9	15	21	28	31	38	44			
d. Variance	3	7	7	7	6	5	7	5	5			

e. Actual Manpower Prior FYs 0

f. Planned Manpower Prior FYs 0

g. Total Estimated Manpower for Contract 65 man months

h. Total Contract Manpower 65 man months

11. Major Milestone Status

a. See attached Detailed Milestone Chart.

b.

c.

d.

e.

f.

g.

h.

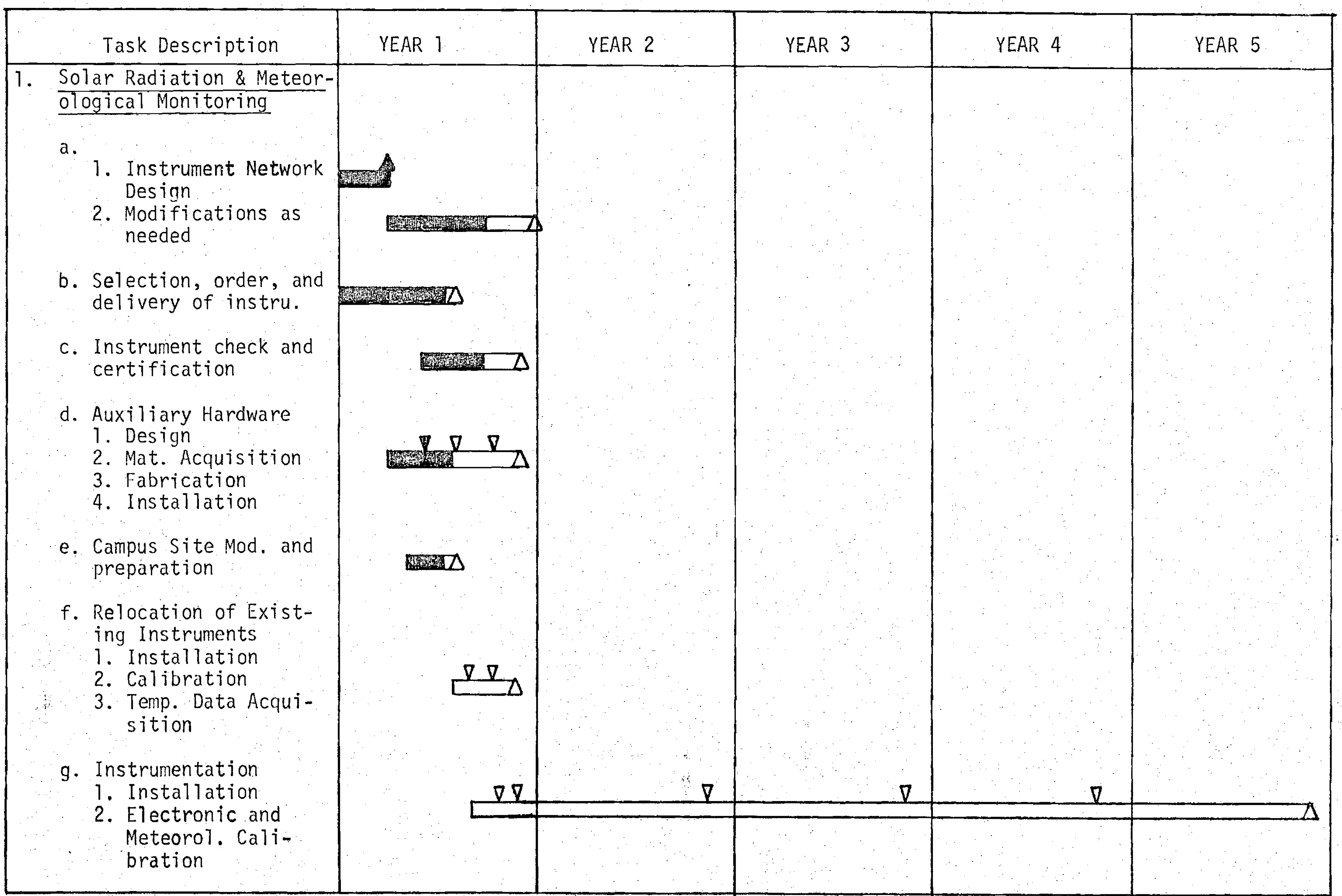
i.

12. Remarks

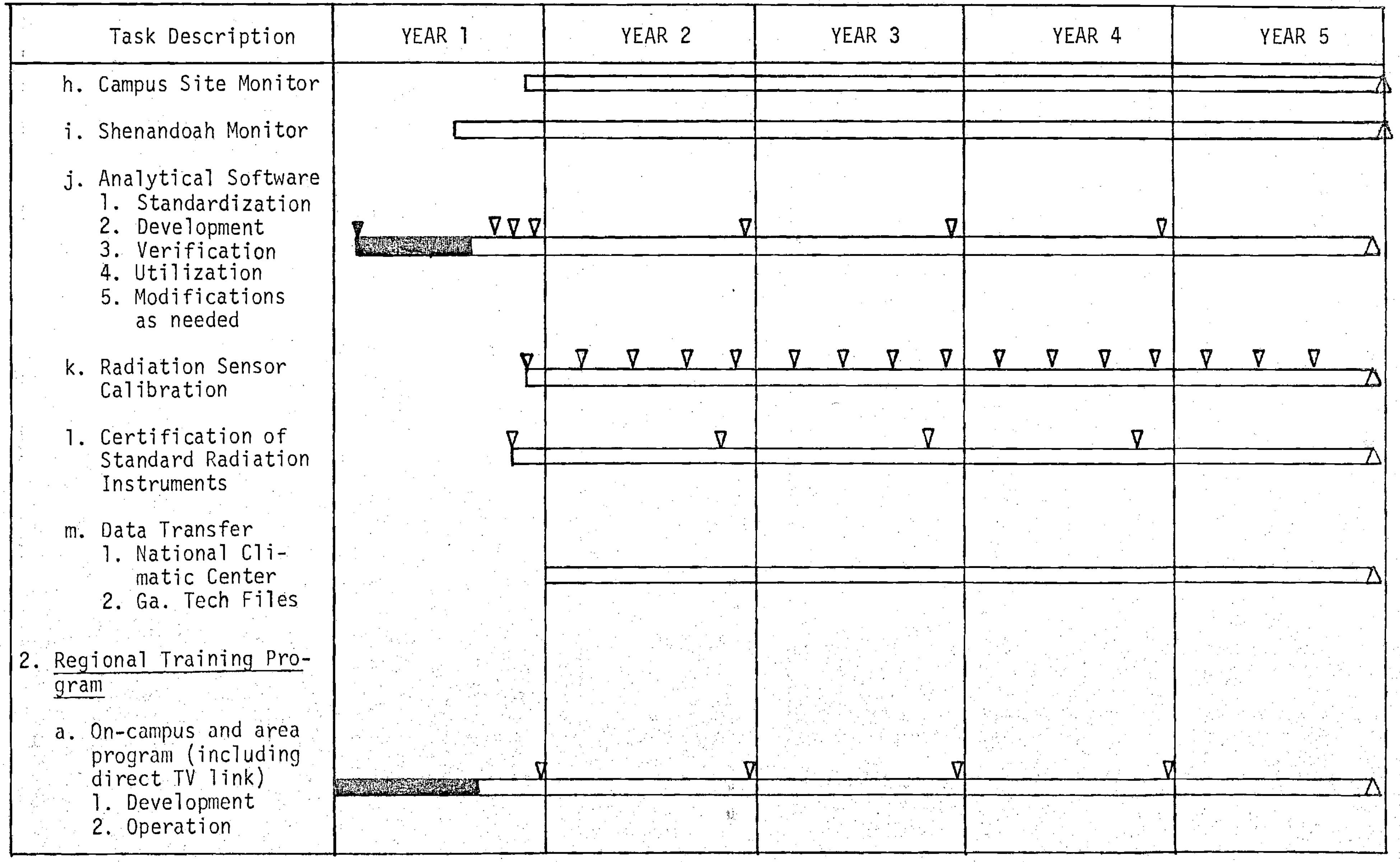
13. Signature of Contractor's Project Manager and Date 7/14/78

14. Signature of Government Technical Representative and Date

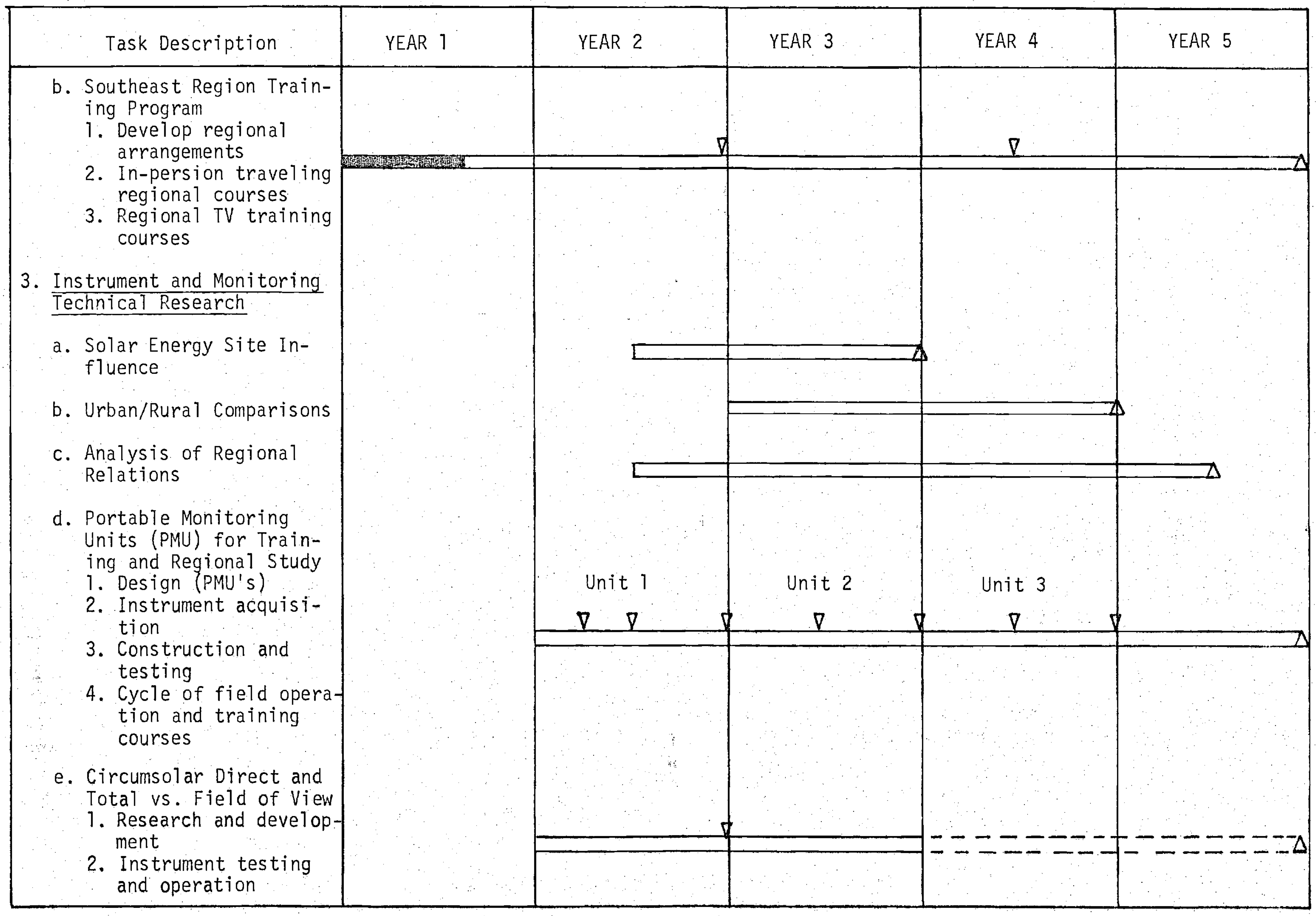
Milestone Chart



Milestone Chart (Cont'd.)



Milestone Chart (Cont'd)



Milestone Chart (cont'd)

Task Description	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
f. Automatic Filter holder for NIP Spectral Data					
1. Research and development		▽	▽		
2. Testing and operation					△
g. Automatic cloud cover camera					
1. Research and development		▽	▽		
2. Testing and operation					△
4. <u>Reports and Review Meetings</u>					
Technical Status Reports	▼ ▼ ▼	▽ ▽ ▽	▽ ▽ ▽	▽ ▽ ▽	▽ ▽ ▽
Review Meeting	▼ ▼	▽ ▽	▽ ▽	▽ ▽	▽ ▽
Technical Progress Reports	▽	▽	▽	▽	▽

E-16-630

ORO/5604-78/4

ANNUAL PROGRESS REPORT

PROJECT NO. E-16-630

PROGRAM FOR SOLAR ENERGY METEROLOGICAL RESEARCH AND TRAINING SITE (REGION 3)

By

C. G. Justus, A. T. Sales, J. I. Craig and J. H. Schlag

Prepared for

THE UNITED STATES DEPARTMENT OF ENERGY
DIVISION OF DISTRIBUTED SOLAR TECHNOLOGY

Under

GRANT EG-77-G-05-5604

Report Period October 1, 1977 – December 31, 1978

January 1979

GEORGIA INSTITUTE OF TECHNOLOGY

Engineering Experiment Station
Atlanta, Georgia 30332

1979

ORO/5604-78/4

PROGRAM FOR SOLAR ENERGY METEOROLOGICAL RESEARCH AND TRAINING SITE (REGION 3)

Annual Progress Report

by

C. G. Justus, A. T. Sales, J. I. Craig, and J. H. Schlag

Georgia Institute of Technology
Atlanta, GA 30332

January, 1979

Report Period October 1, 1977 - December 31, 1978

PREPARED FOR THE UNITED STATES
DEPARTMENT OF ENERGY

DIVISION OF DISTRIBUTED SOLAR TECHNOLOGY

UNDER GRANT EG-77-G-05-5604

Georgia Tech Project E-16-630

EXECUTIVE SUMMARY

Eight regional university Solar Energy Meteorological Research and Training Site (SEMRATS) Program sites have been established around the United States. The Georgia Institute of Technology is the SEMRATS center for the Southeastern Region, including Florida, Georgia, Alabama, Mississippi, Tennessee, South Carolina, North Carolina, Virginia, Kentucky, West Virginia, Maryland, the District of Columbia, and Delaware. Permanent monitoring sites on the Georgia Tech campus and at Shenandoah, about 50 km (30 mi) southwest of the campus site, will continuously monitor and record global, direct, diffuse, global tilted, UV, IR, and other spectral radiation parameters. A careful program of instrument and electronic calibration and quality control will insure the accuracy of these recorded data. This report describes the sites and instrumentation, the electronics signal conditioning and averaging, and the quality control software used in the monitoring program. Some preliminary regional studies of available radiation patterns and some results of a national absolute radiometer intercomparison are also presented.

TABLE OF CONTENTS

LIST OF FIGURES

Figure		Page

LIST OF TABLES

1. PROJECT OBJECTIVES

This broad program of solar energy and meteorological monitoring, training, and research has the following main objectives for the proposed 5 years duration:

(1) to provide for the Southeast Region (Region 3) a set of continuously monitored and quality controlled data on solar radiation and atmospheric phenomena related to solar energy collection, conversion, and storage, and to relate these to the extensive ongoing solar energy research and engineering projects carried out by Georgia Tech and in the Southeast Region.

(2) by analysis of monitoring results at two sites (on campus, adjacent to the Georgia Tech Advanced Components Test facility and off-campus adjacent to the Shenandoah Solar Total Energy Site), determine: a) optimum siting of solar radiation and meteorological monitoring instruments relative to solar energy systems to provide the most representative site data with the least influence from the solar collector systems, b) adequacy and representativeness for the Southeast Region of various methodologies for relating easily measured phenomena (minutes of sunshine, cloud cover, etc.) to engineering quality solar radiation data (direct, diffuse, and global insolation, etc.).

(3) to establish and maintain a training program which will allow: a) undergraduate and graduate engineering students, through elective or minor courses, to become informed in the areas of meteorology and atmospheric science as they relate to solar and wind

energy, b) graduate students in the atmospheric sciences to become informed of the specific requirements of monitoring, analysis, interpretation and presentation of meteorological information related to engineering aspects of solar and wind energy, c) professionals in various fields, through short courses and seminars, to become familiar with the new and rapidly developing aspects of solar energy engineering and technology, especially the radiation monitoring and meteorological aspects of this field.

(4) through cooperation in the 3/2 dual degree program, the National Consortium for Graduate Degrees for Minorities in Engineering and other academic programs, enhance the opportunities for minorities (especially Black American and Puerto Ricans) and women in the solar energy engineering and technology field.

(5) instrumentation and monitoring techniques research and development to enhance the engineering applicability of the solar radiation and meteorological monitoring and to provide better instructional tools through low cost instrument systems for educational purposes.

(6) to investigate, with the fixed site instruments and the portable monitoring units (PMU's), the influence of urban haze and aerosols as well as the high levels of natural turbidity which occur in parts of the Southeast region, and with the PMU's to sample the effects on solar radiation of a wide variety of geography (which spans coastal, piedmont plains, and mountainous within the Southeast Region).

2. THE ON-CAMPUS SITE

The main solar radiation/meteorological monitoring site is located on the roof of the Civil Engineering (CE) building on the Georgia Tech campus, which is about 3 km (2 mi) from the center of downtown Atlanta. Figure 1 shows the location of the CE building site and two nearby solar and wind energy facilities -- the 400 kW Advanced Components Test Facility (a central tower receiver focusing collector array), and the 15 kW Wind Turbine Test Facility (with a Grumman Windstream 25). Figure 2 shows a detail of the new installation on the CE roof. All of the radiation monitoring instruments are located on the new instrument platform at the southeast corner of the roof. A photograph of the instrumentation on the pad is shown in Figure 3. A complete list of the instrumentation on the CE roof site is given in Table 1. Global and diffuse measurements employ Eppley Precision Spectral Pyranometers (PSP's) with an added air blower ring for dew/frost protection. Figure 4 shows a PSP with the dew protection ring mounted in an Eppley tracking shadow disk for diffuse measurements.

Meteorological data recorded continuously at the nearby Wind Turbine Test Facility can also be merged into the main data set. Table 2 lists the meteorological parameters recorded at this facility.

The horizon as viewed from the main CE roof site is shown in Figure 5. The largest obstruction is the Coca Cola headquarters building 9° to 12° east of south, with elevation blockage from 8½° to 9°. Figure 6 shows a schematic view of the horizon obstruction with azimuths and elevations indicated and solar tracks at equinoxes and solstices delineated on the same figure.

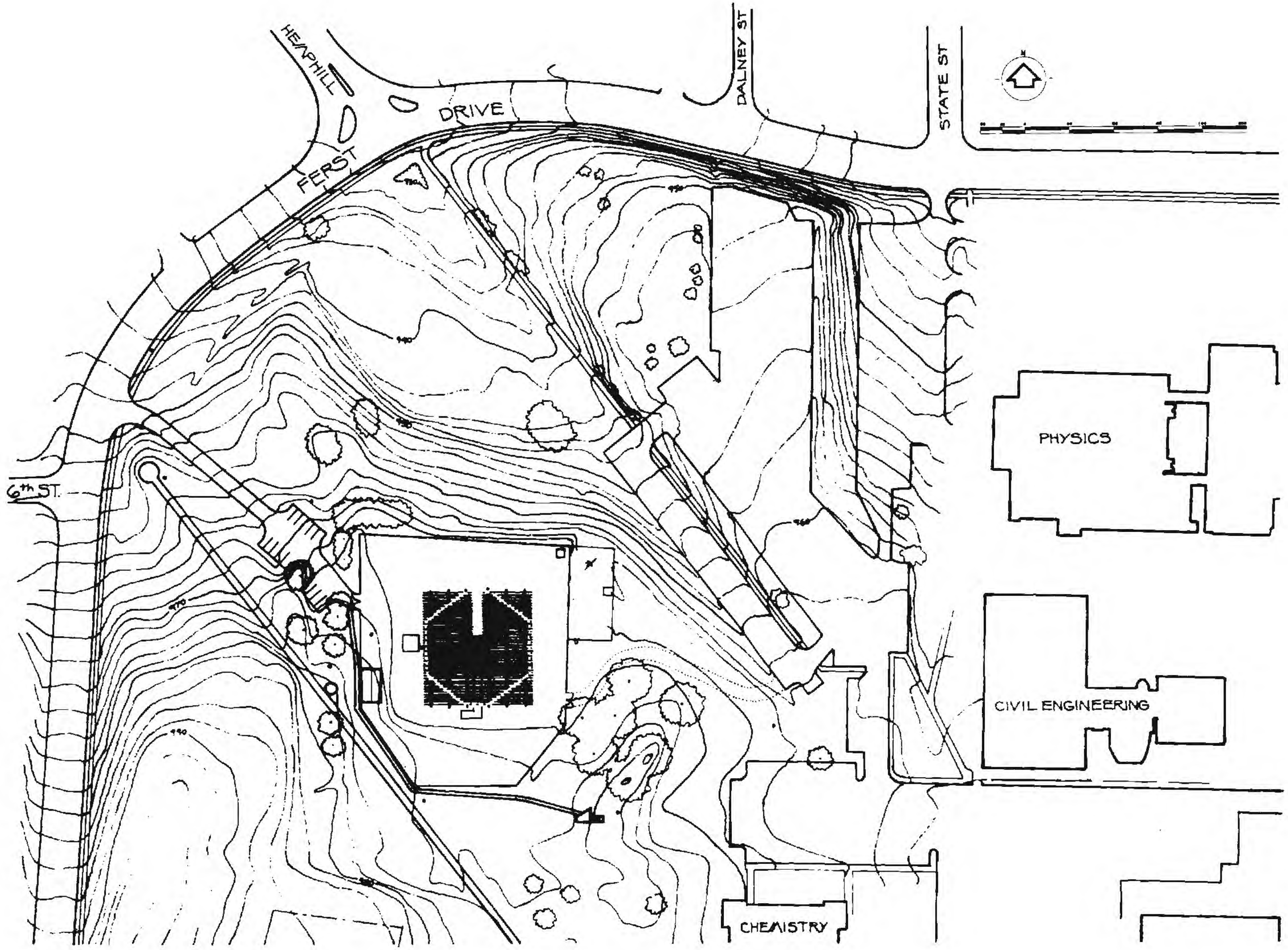
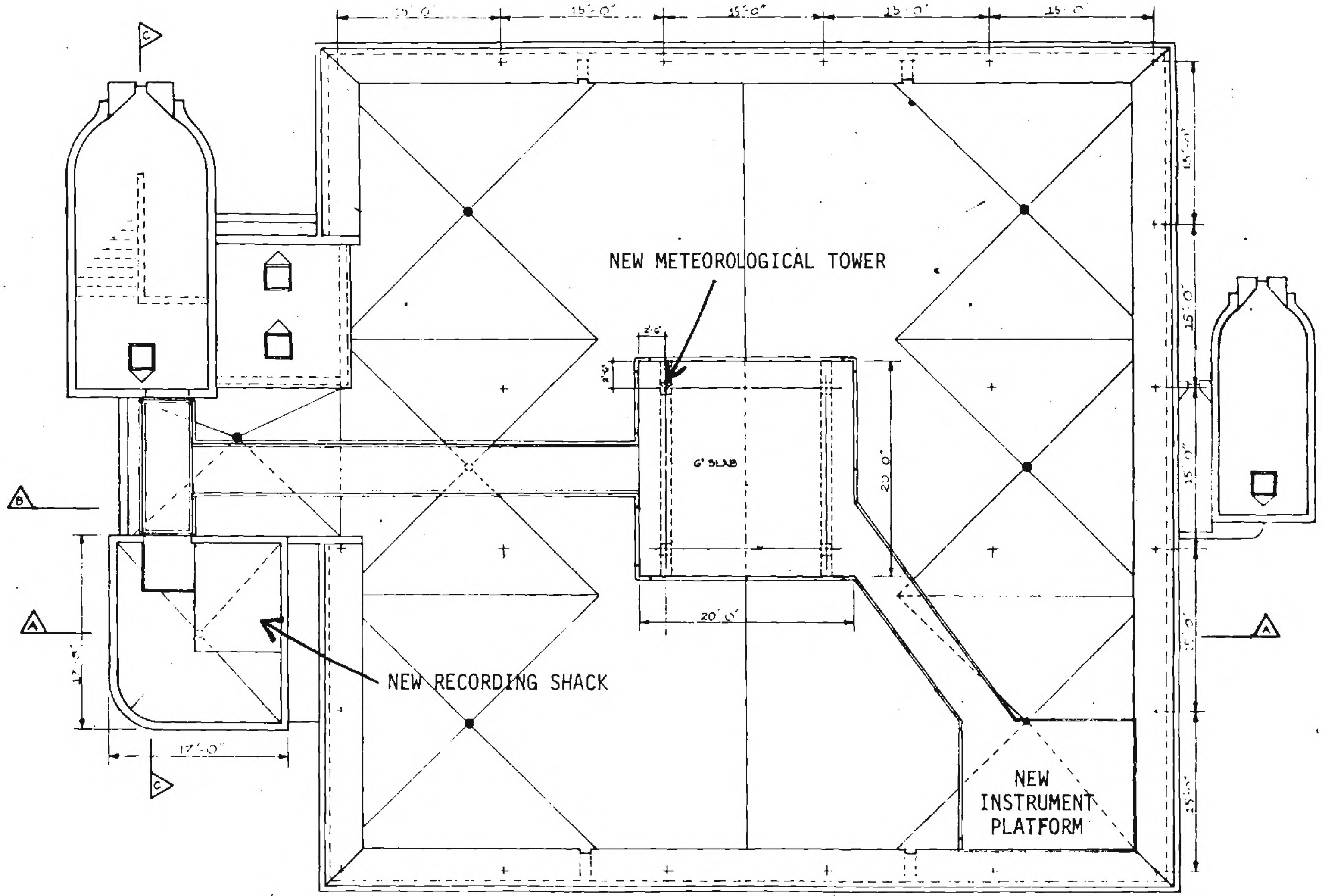


Figure 1. Campus Layout of Georgia Tech Solar Thermal Test Facility, Wind Turbine Test Facility, and Civil Engineering Building Site



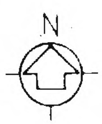


Figure 2. Plan View of Civil Engineering Showing Layout of New Facilities on Roof

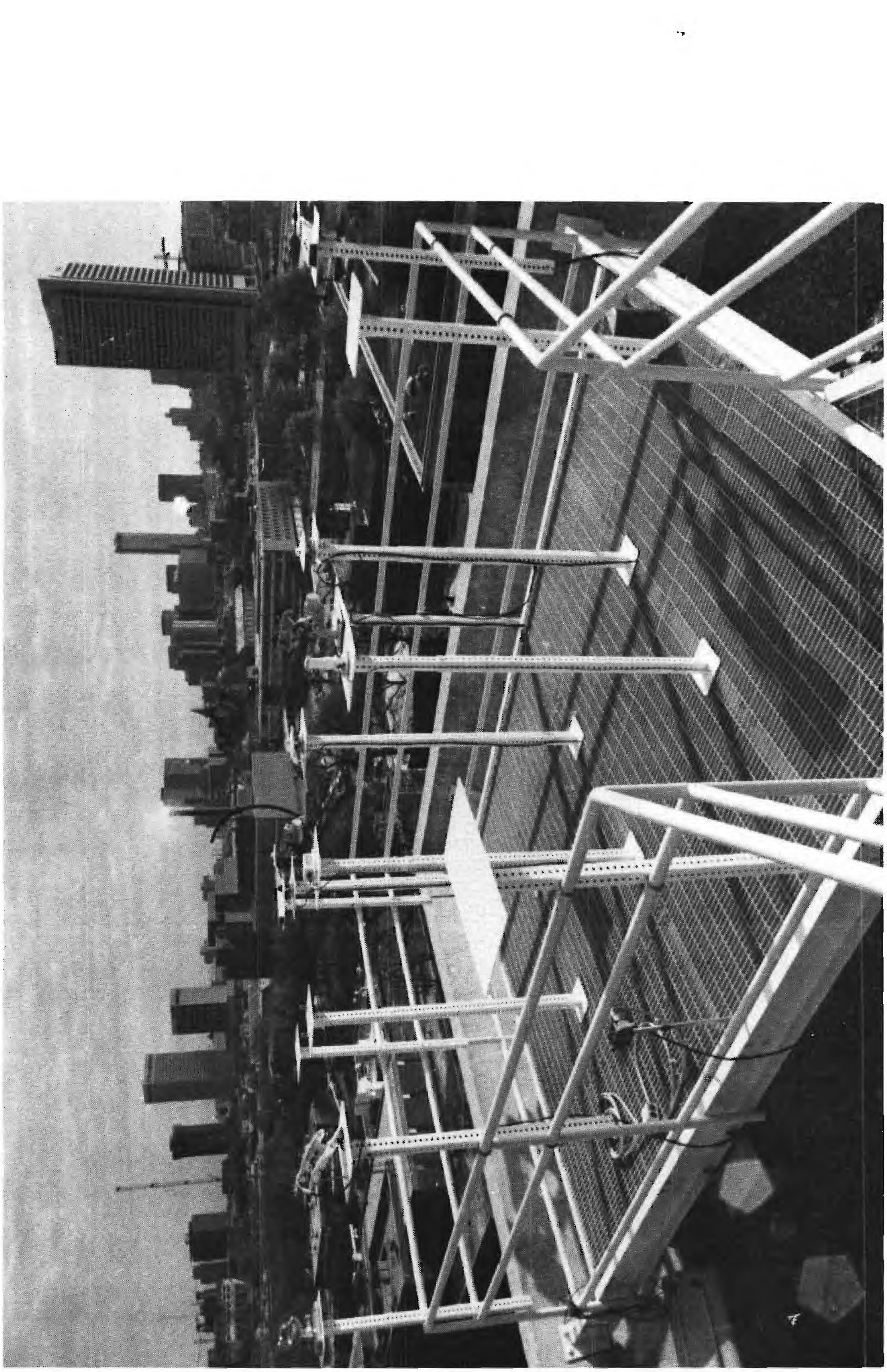


Figure 3. Solar Instrumentation Pad on C. E. Roof

Table 1

Georgia Tech, Campus Site, C. E. Roof

Latitude = 33° 46' 37" N
Longitude = 84° 23' 54" W
Time Zone = Eastern (5)

	Elevation		Orientation		Spectral Band μ		
Element	MSL, m	AGL, m	Azimuth	Tilt	Lower	Upper	Description
1000	326.8	34.8	0	0	0.29	2.80	global, PSP
1001	326.8	34.8	0	0	0.63	2.80	global spectral, PSP + RG2
1002	326.8	34.8	0	0	0.29	2.80	global, Spectrolab SR75
1003	326.8	34.8	0	0	0.38	1.20	global, Dodge Products Solar Cell
1004	326.8	34.8	0	0	0.38	1.20	global, Lambda Solar Cell
1460	326.8	34.8	180	34	0.29	2.80	global tilted at lat., PSP w/artificial horizon
2010	326.8	34.8	0	0	0.29	2.80	direct normal, NIP
2011	326.8	34.8	0	0	0.63	2.80	direct normal spectral, NIP + RG2
2012	326.8	34.8	0	0	0.29	2.80	direct, TMI active cavity
3000	326.8	34.8	0	0	0.29	2.80	diffuse, PSP + disk
3001	326.8	34.8	0	0	0.63	2.80	diffuse spectral, PSP + disk + RG2
5000	326.8	34.8	0	0	0.30	0.39	UV, Eppley TUVR
6000	326.8	34.8	0	0	0.30	60.0	total incoming, CSIRO
9020	326.8	34.8	-	-	--	--	minutes of sunshine, Campbell Stokes
9021	326.8	34.8	-	-	--	--	minutes of sunshine, from NIP
9120 (?)	326.8	34.8	-	-	--	--	nephelometer Bscat
9150	326.8	34.8	-	-	--	--	rainfall
9170 (?)	326.8	34.8	-	-	--	--	turbidity τ (500 nm)
9200	332.9	40.9	-	-	--	--	wind direction, lower level
9201	343.3	51.3	-	-	--	--	wind direction, upper level
9210	332.9	40.9	-	-	--	--	wind speed, lower level
9211	343.3	51.3	-	-	--	--	wind speed, upper level
9300	329.8	37.8	-	-	--	--	dry bulb temperature, lower level
9301	343.0	51.0	-	-	--	--	temperature difference, upper minus lower level
9302	326.8	34.8	-	-	--	--	temperature in CSIRO bottom cavity
9320	329.8	37.8	-	-	--	--	dewpoint temperature, lower level
9321	343.0	51.0	-	-	--	--	dewpoint temperature, upper level
9330 (?)	326.8	34.8	-	-	--	--	relative humidity in nephelometer air train
9350 (?)	326.8	34.8	-	-	--	--	precipitable water, sun photometer
9400	326.8	34.8	-	-	--	--	station pressure
9500 (?)	326.8	34.8	-	-	--	--	ozone concentration

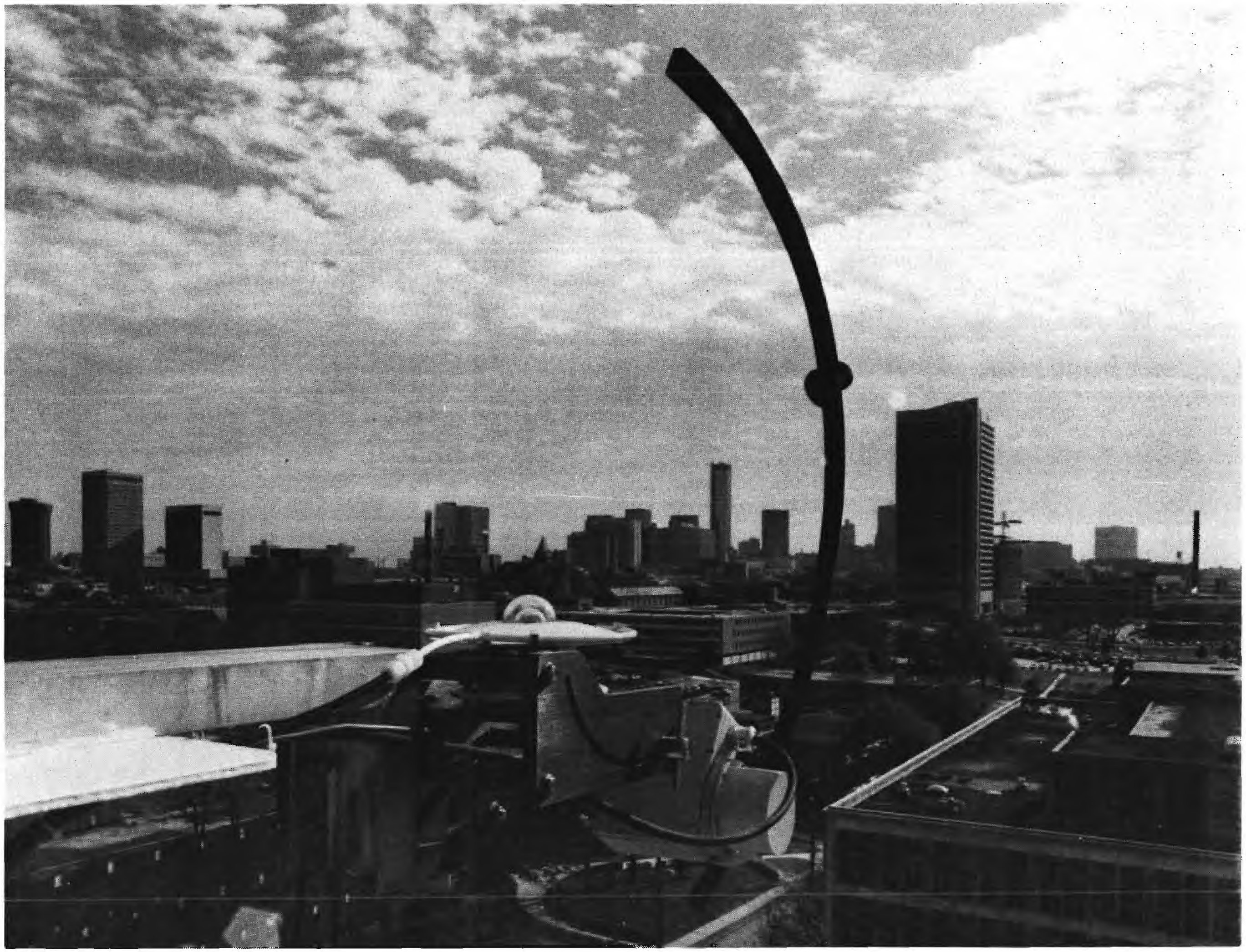


Figure 4. Eppley PSP On Diffuse Tracking Mount with Dew/Frost Blower Ring

Table 2

Georgia Tech, Campus Site, Wind Turbine Test Facility
(Element numbers assume merging with C.E. roof site data)

Latitude = 33° 46' 38" N
Longitude = 84° 24' 3" W
Time Zone = Eastern (5)

	Elevation		Orientation		Spectral Band μ		
Element	MSL, m	AGL, m	Azimuth	Tilt	Lower	Upper	Description
9151	296.9	1.2	-	-	--	--	rainfall
9202	302.4	6.7	-	-	--	--	wind direction, lower level
9203	313.4	17.7	-	-	--	--	wind direction, upper level
9212	302.4	6.7	-	-	--	--	wind speed, lower level
9213	313.4	17.7	-	-	--	--	wind speed, upper level
9302	298.7	3.0	-	-	--	--	temperature, lower level
9303	313.4	17.7	-	-	--	--	temperature difference, upper minus lower level
9331	298.7	3.0	-	-	--	--	relative humidity, lower level
9332	313.4	17.7	-	-	--	--	relative humidity, upper level
9401	296.9	1.2	-	-	--	--	station pressure

Figure 5. Panorama View from C. E. Roof Site

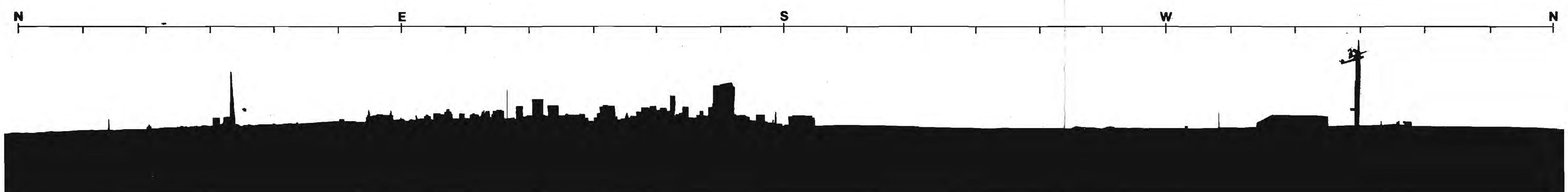


Figure 6. Schematic Panorama from C. E. Roof, Showing Solar Tracks and Solstices and Equinox (Vertical Scale Expanded)

3. THE SHENANDOAH SITE

A second monitoring site is located at Shenandoah, a new-town approximately 50 km (30 mi) southwest of the main campus site. The Shenandoah site was initiated in connection with the Georgia Solar Total Energy Project, and utilizes the EG & G portable data logger system (see Figure 7). The original 8 parameters to be monitored at Shenandoah have been augmented by 8 more for this project. The complete list is given in Table 3.

Data recording at Shenandoah is done, via the EG & G data logger, onto TMI format tape cassettes. These cassettes are picked up by the personnel who do the routine site maintenance and are brought to the campus for computer processing.

As at the on-campus site, diffuse radiation is measured with an Eppley tracking shade disk, and global radiation on a tilted surface is measured at latitude tilt with an artificial horizon system (not shown) to reduce as much as possible the below-horizon tilted component, for the sake of uniformity of measurements among the sites. Otherwise radiation on a tilted surface has a component which depends on the albedo of the foreground reflecting surface.

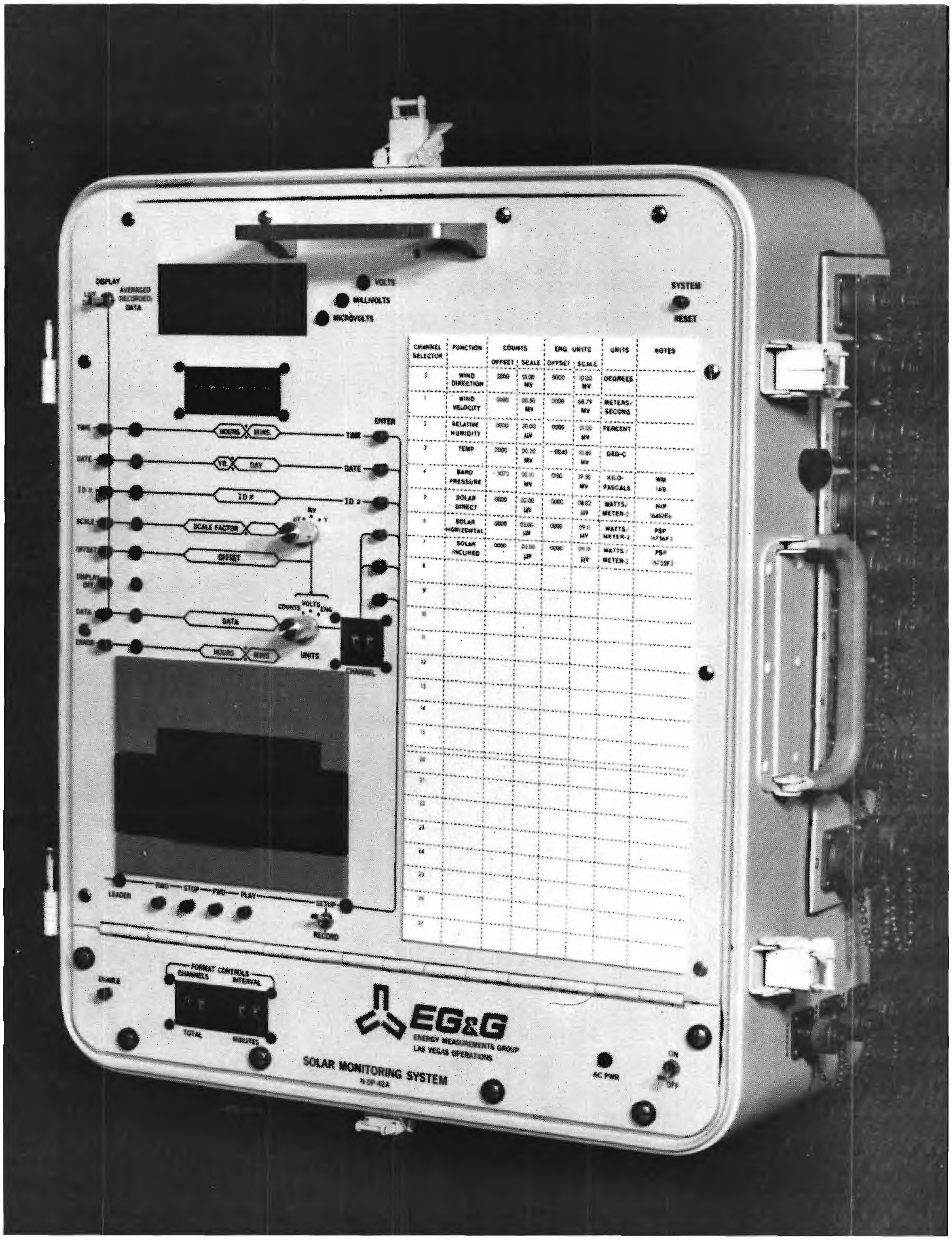


Figure 7. New EG & G Data Logger at Shenandoah Site

Table 3

Georgia Tech, Shenandoah Site

Latitude = 33° 24' 09" N
Longitude = 84° 45' 01" W
Time Zone = Eastern (5)

	Elevation		Orientation		Spectral Band μ		
Element	MSL, m	AGL, m	Azimuth	Tilt	Lower	Upper	Description
1000	289.5	1.2	0	0	0.29	2.80	global, PSP
1001	289.5	1.2	0	0	0.63	2.80	global spectral, PSP + RG2
1460	289.5	1.2	180	33	0.29	2.80	global tilted at lat., PSP + artificial horizon
2010	289.5	1.2	0	0	0.29	2.80	direct, NIP
2011	289.5	1.2	0	0	0.29	2.80	direct, NIP (redundant)
2012	289.5	1.2	0	0	0.63	2.80	direct spectral, NIP + RG2
3000	289.5	1.2	0	0	0.29	2.80	diffuse, PSP + disk
5000	289.5	1.2	0	0	0.30	0.39	UV, Eppley TUVR
6000	289.5	1.2	0	0	0.30	60.0	total incoming, CSIRO
9150	289.5	1.2	-	-	--	--	rainfall
9200	290.7	2.4	-	-	--	--	wind direction
9210	290.7	2.4	-	-	--	--	wind speed
9300	290.1	1.8	-	-	--	--	dry bulb temperature
9301	289.5	1.2	-	-	--	--	temperature in CSIRO bottom cavity
9330	290.1	1.8	-	-	--	--	relative humidity
9400	290.1	1.8	-	-	--	--	station pressure

4. SIGNAL CONDITIONING AND AVERAGING CIRCUITRY

In order to minimize the influence of RF interference (e.g. from the nearby student radio transmitting tower), output from each radiation monitoring instrument is run to its amplifier on the pad, to boost the signal to the 10 volt level. The basic amplifier design is shown in Figure 8. Gain of each amplifier can be set by selecting a combination of fixed and adjustable resistors, to allow the peak output voltage to correspond to a fixed radiation level, based on the exact calibration of the particular sensor involved.

Averaging of each data channel is done by a signal averaging circuit called the Voltage Monitor, illustrated in Figures 9-11. Figure 9 is a functional block diagram, Figure 10 is a circuit board layout, and Figure 11 is a pin identification chart for the Voltage Monitor unit. A parts list is included with Figure 10.

The Voltage Monitor is a general purpose averaging circuit designed to measure signals in the 0-10 volt range. Both an analog output and a digital display of the average signal voltage are provided. The length of the averaging period is selected by the REAL TIME CLOCK frequency (Figure 11).

Supply voltages are +15, -15, and +5 volts. Typically 650 mA is drawn from the 5 volt source, with approximately 100 mA driving the four seven-segment displays. (A separate connection is available for dedicating a 5 volt supply to the display). If the BLANKING INPUT (Figure 11) is left ungrounded, the display will be inhibited. Current requirements for the +15 and the -15 volt sources are about 25 mA and

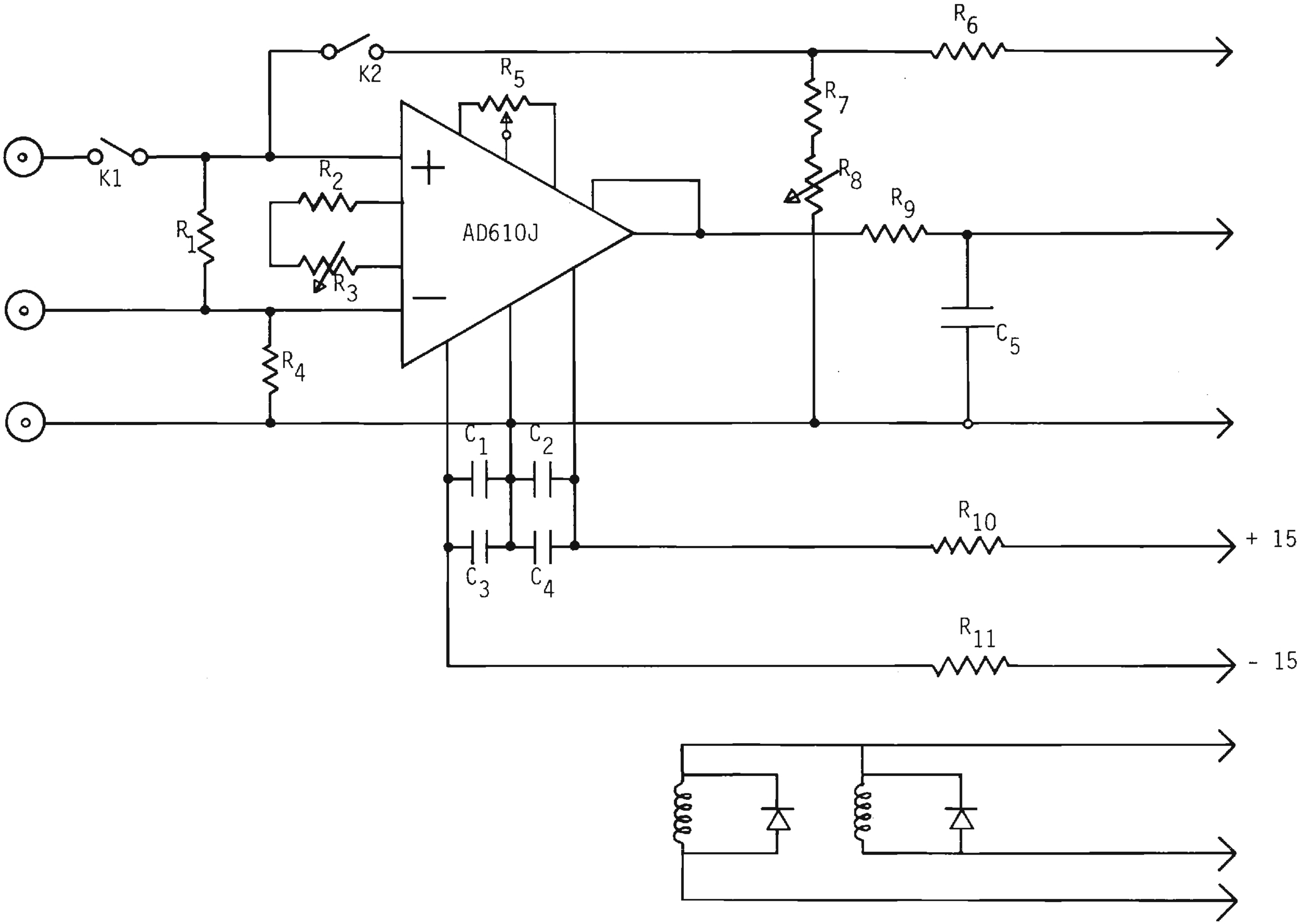


Figure 8. Amplifier Circuit Diagram

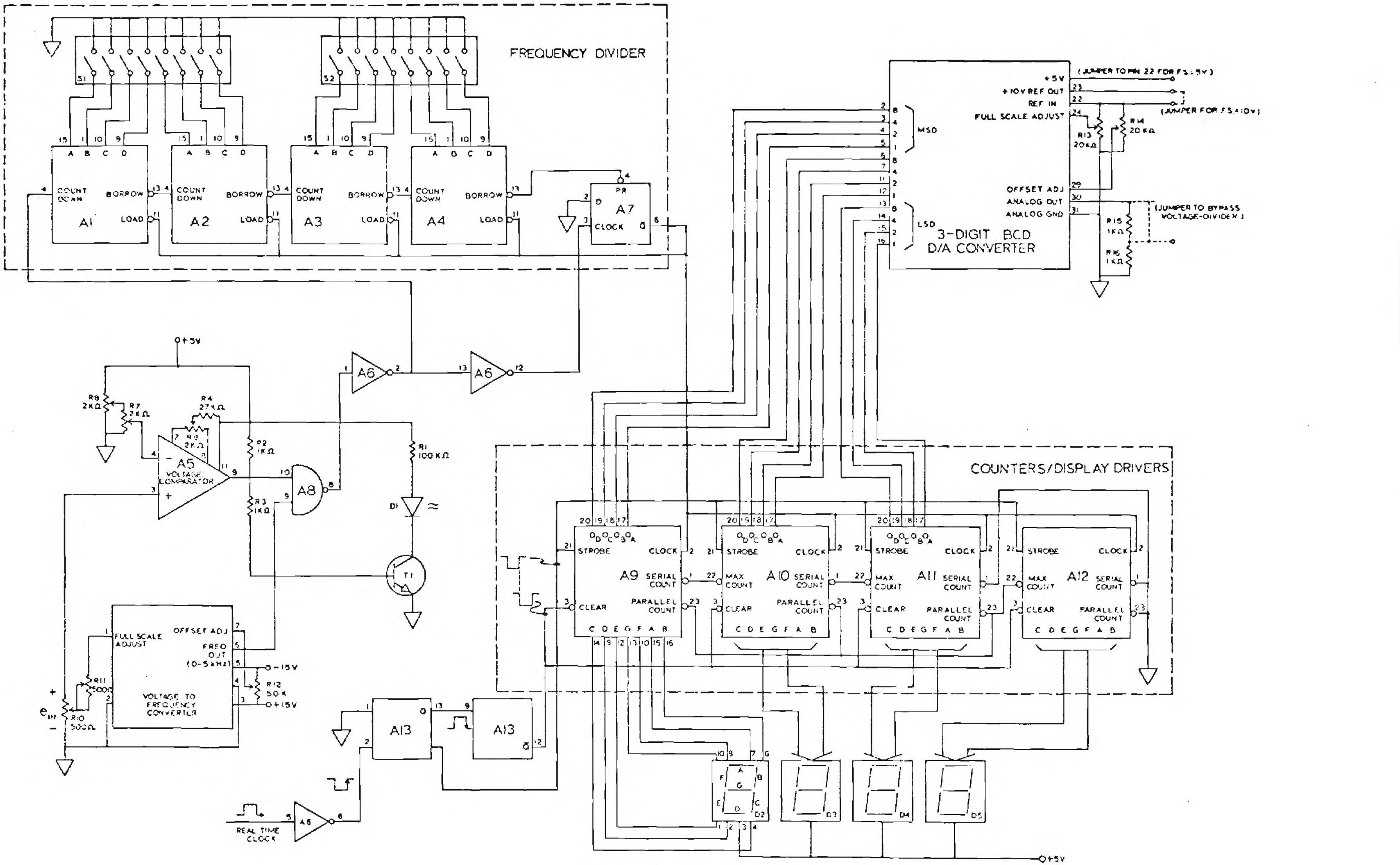
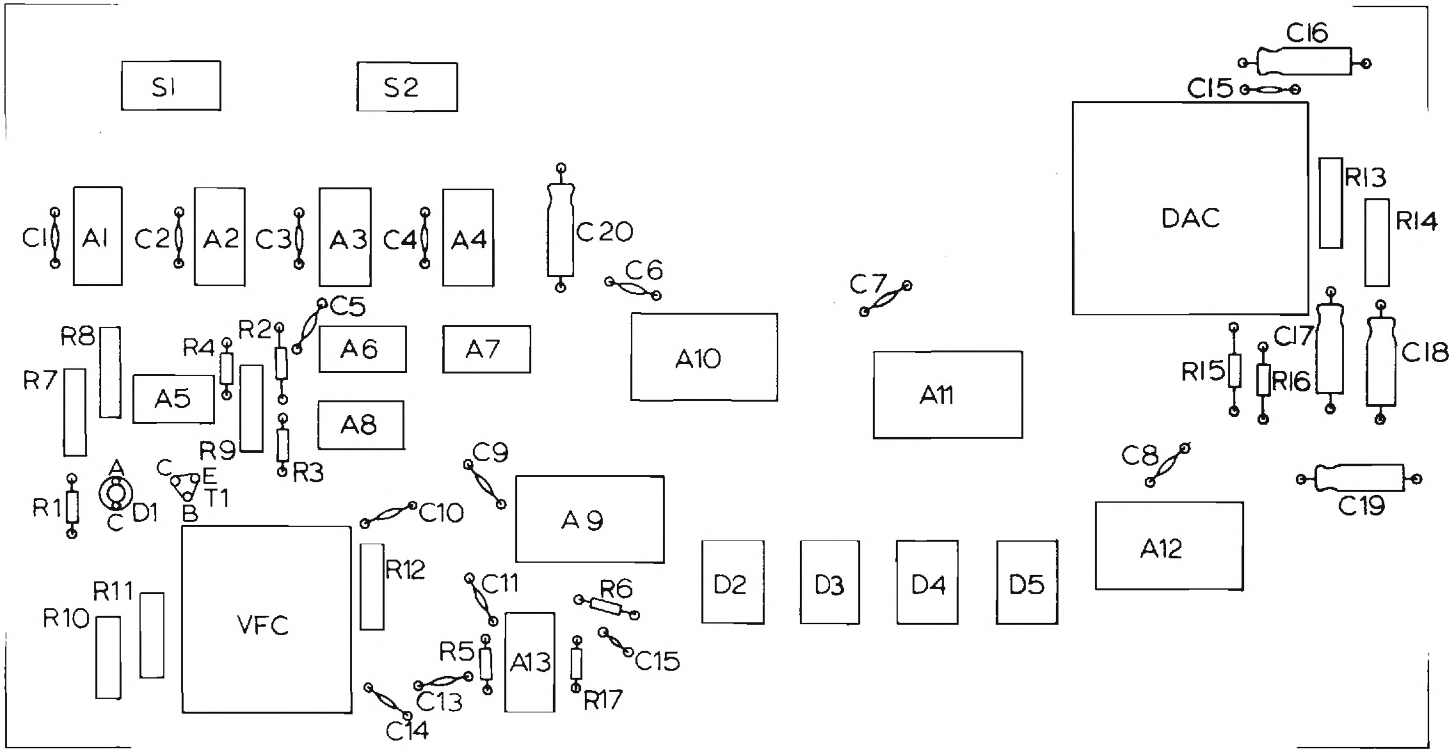


Figure 9. Circuit Diagram for Averaging Circuit



PARTS LIST		A 9-12	74143	R 1	100Ω ¼W	R 15-16	1kΩ PRECISION
		A 13	74221	R 2-3	1kΩ ¼W	R 17	330Ω ¼W
A 1-4	74193	C 1-15	.0047μF	R 4-6	2.7kΩ ¼W	S 1-2	DIP SWITCHES
A 5	LM311	C 16-20	15μF	R 7-9	2kΩ TRIM POT	T 1	2N3904
A 6	7414	D 1	INDICATOR (LED)	R 10-11	500Ω TRIM POT	VFC	456J
A 7	7474	D 2-5	CLT2140	R 12	50kΩ TRIM POT		(ANALOG DEVICES)
A 8	7438	DAC	ZD433 (ZELTEX)	R 13-14	20kΩ TRIM POT		

Figure 10. Circuit Board Layout for the Averaging Circuit

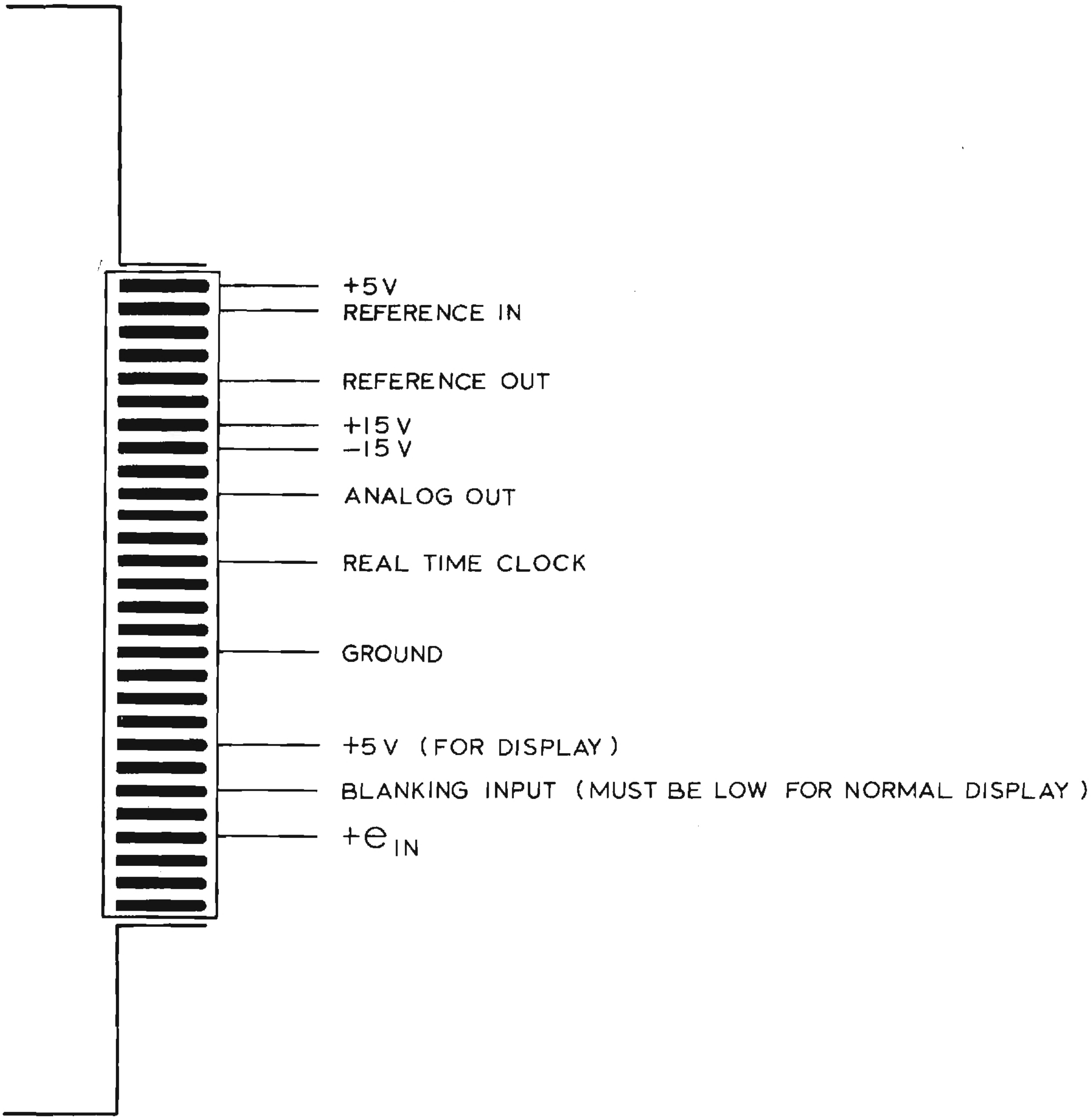


Figure 11. Pin Identification Chart for the Averaging Circuit

10 mA respectively.

The input signal $+e_{in}$ is translated to a proportional frequency by the voltage-to-frequency converter (1000 Hz/volt). If the input voltage falls below the reference level of the voltage comparator (A5), the counters will be disabled. This reference level can be changed by adjusting potentiometers R7 and R8. Indicator D1 will be biased on as long as the counters are enabled.

The number which will appear on the 4-digit display bears the following proportional relationship to the input voltage:

$$n = kv$$

n = number displayed

v = input signal voltage

k = 1000 Hz/volt x 1/N x t

where t is the period of the real time clock and N is the divisor imposed by the frequency-divider network (Figure 9). N is selected by setting the DIP switches to a binary representation of N-1. The leftmost switch corresponds to the least significant bit; a depressed switch indicates a binary "1". So, in order to divide by 10, for example, the first and fourth switches (from left) should be depressed).

The real time clock pulse generates a strobe signal (Figure 9) to the counter/display drivers A9-A12. This updates the display to reflect the current contents of the counter. Another pulse, triggered by the trailing edge of the strobe, clears the counter. So, at the end of every clock cycle, the display is "refreshed" and the counter is reset to zero.

If the period of the real time clock (i.e. the averaging time) is

N seconds, the display will show 1000 counts per volt. Hence, a direct representation of the input voltage will be displayed if the decimal point on D2 is enabled. This is accomplished by cutting the path from pin 7 of A9 to ground. (If the cut is made between the two extra pads on this path, a simple jumper may be added later to suppress the decimal point).

The three most significant digits of the display are connected to the BCD inputs of the D/A converter. In order for the voltage at ANALOG OUT (Figure 11) to equal the average of the input signal, it may be necessary to replace R_{15} by a jumper (Figure 1). The need for this modification will depend on the input voltage range, the voltage applied to REF IN (Figure 11) and the proportional relationship between the display and the input signal. REF IN determines the full scale output of the D/A converter. For a 0-10 volt output range, tie REF OUT to REF IN.

5. QUALITY CONTROL SOFTWARE

The overall software design for performing quality control, analysis, and archival of the solar radiation and meteorological data will be implemented on the Georgia Tech CDC CYBER 70/74 computer system and an INTERDATA 7/32 computer system also located at Georgia Tech. It is anticipated that the system will normally operate on the INTERDATA with the CYBER used as backup.

Referring to Figure 12, the software will consist of an input module, an automatic quality control module, a manual quality control module, the clear sky radiation model, and several archival modules.

All bookkeeping records will be maintained on an auxiliary disk file. The bookkeeping records will contain the following information:

1. Status of archival tapes (time period represented by the data on the tapes)
2. Status of input data (time and date represented by the most recent input data)
3. Sensor information (includes calibration data, channel assignments, and information about the sensor to be stored with the archived data).

The input module will accept data from tapes produced by the data logging equipment and manual inputs. Submodules may be added later to the input module to permit input from other sources. The input module will (a) convert all input to a standard format for input to the automatic quality control module and (b) merge, based on date and time, data from all input sources.

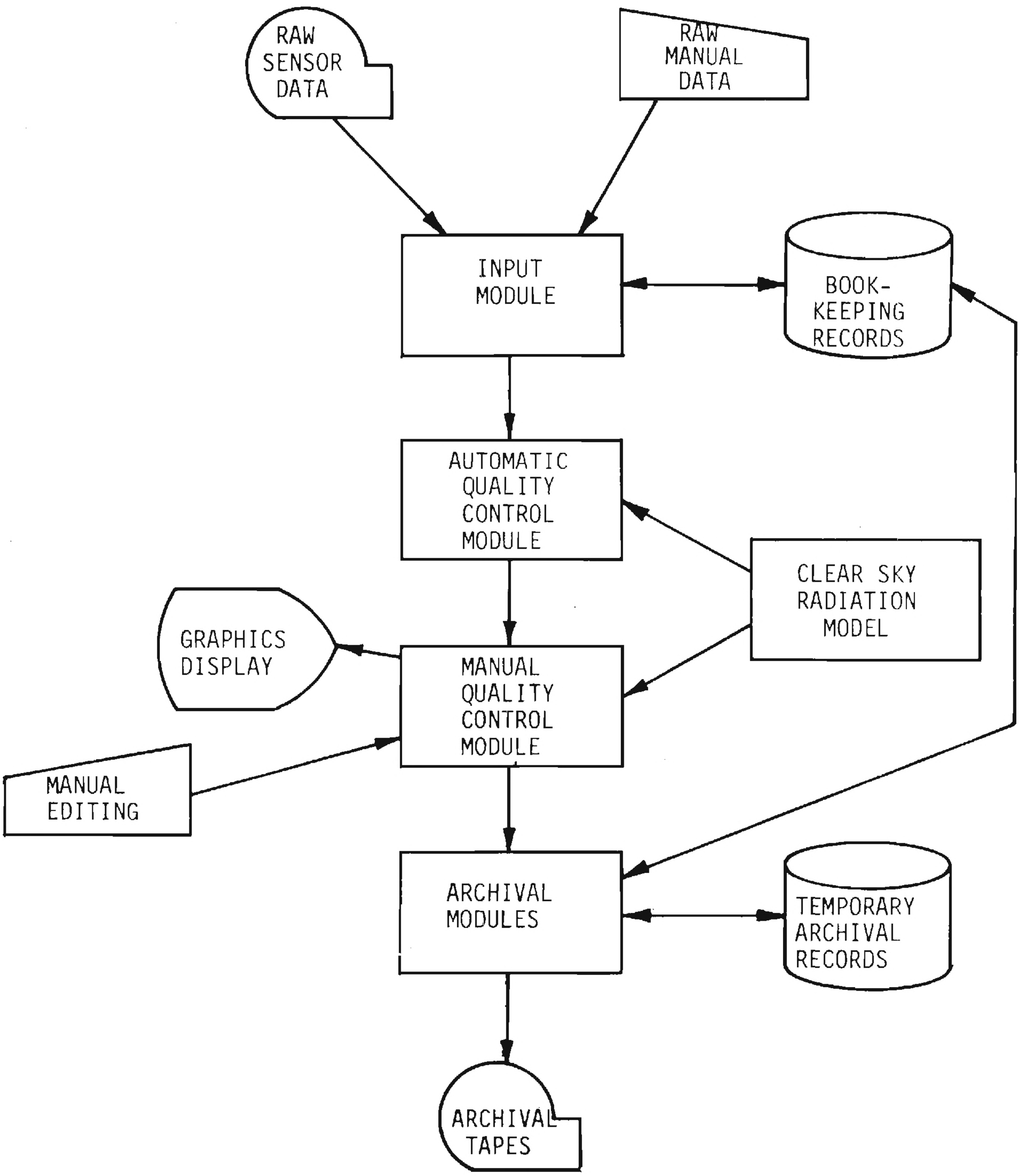


Figure 12. Solar Radiation and Meteorological Data Storage System

The automatic quality control module will perform tests on the input data to determine gross validity for specific sensors. The data will be appropriately tagged to indicate the results of quality control tests.

The manual quality control module will be available to permit project personnel to flag and possibly delete or modify data based on professional judgement. Data from one sensor over a period of time may be graphically displayed with data from other sensors or models superimposed on the same plot. Individual data values and automatic quality control flags may be displayed in tabular format. Editing capabilities will exist to modify the flags and possibly delete or modify data.

The archival modules will store the quality checked data, flags, and sensor information on tape in the format required by the National Climatic Center in Asheville, N.C. Each month tapes will be produced containing hourly records of 1 minute values for each sensor and daily records of hourly values for each sensor. Each year a tape will be produced containing monthly records of daily values for each sensor and annual records of monthly values for each sensor. All tapes will contain station records for each sensor.

6. MODEL COMPARISONS

A model for direct, diffuse, and global radiation, developed by Watt Engineering* has been programmed for the computer for use in the quality control of the measured data. If automated percent sunshine, turbidity, and precipitable water measuring systems can be developed, these will provide real time (e.g. hourly basis) values for all of the necessary input parameters for the Watt model. At least the hourly percent sunshine will be used, as measured by the Campbell Stokes sunshine duration recorder, even if automated devices are not developed soon.

Figures 13-18 show observed 10 minute (+'s) and hourly (∇'s) data observed between about 10 am and 3 pm on two days, compared with calculated values using climatological values for percent sunshine, turbidity, and precipitable water. As these figures show, 9/13 is a more cloudy day than 9/19. During clear periods, the clear sky direct beam model compares well with observations. However, some adjustment from climatological values would be necessary to get a better comparison of model and observed diffuse radiation.

---

*On the Nature and Distribution of Solar Radiation, HCP/T2552-01

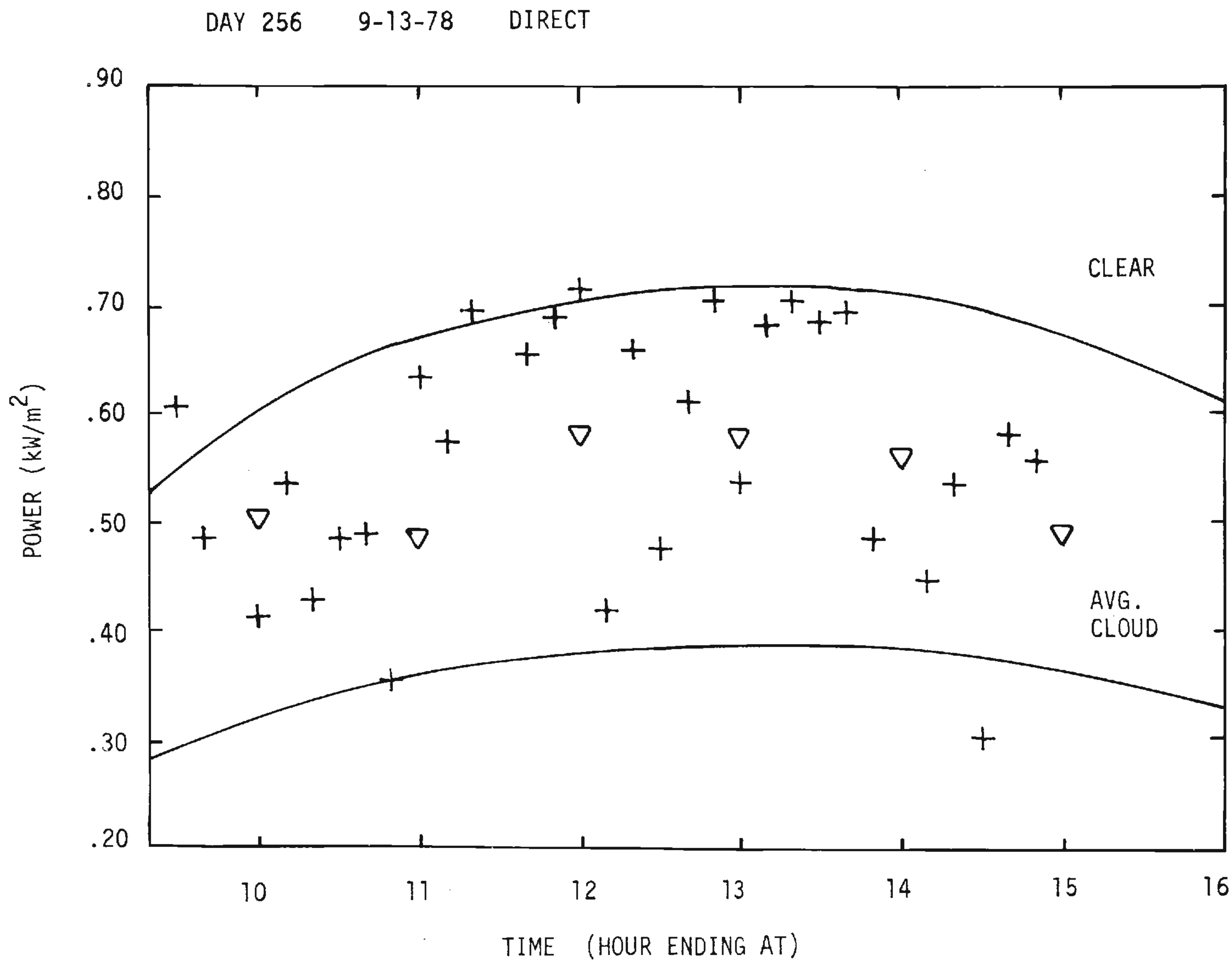


Figure 13. Observed and Modeled Direct Radiation 9/13/78

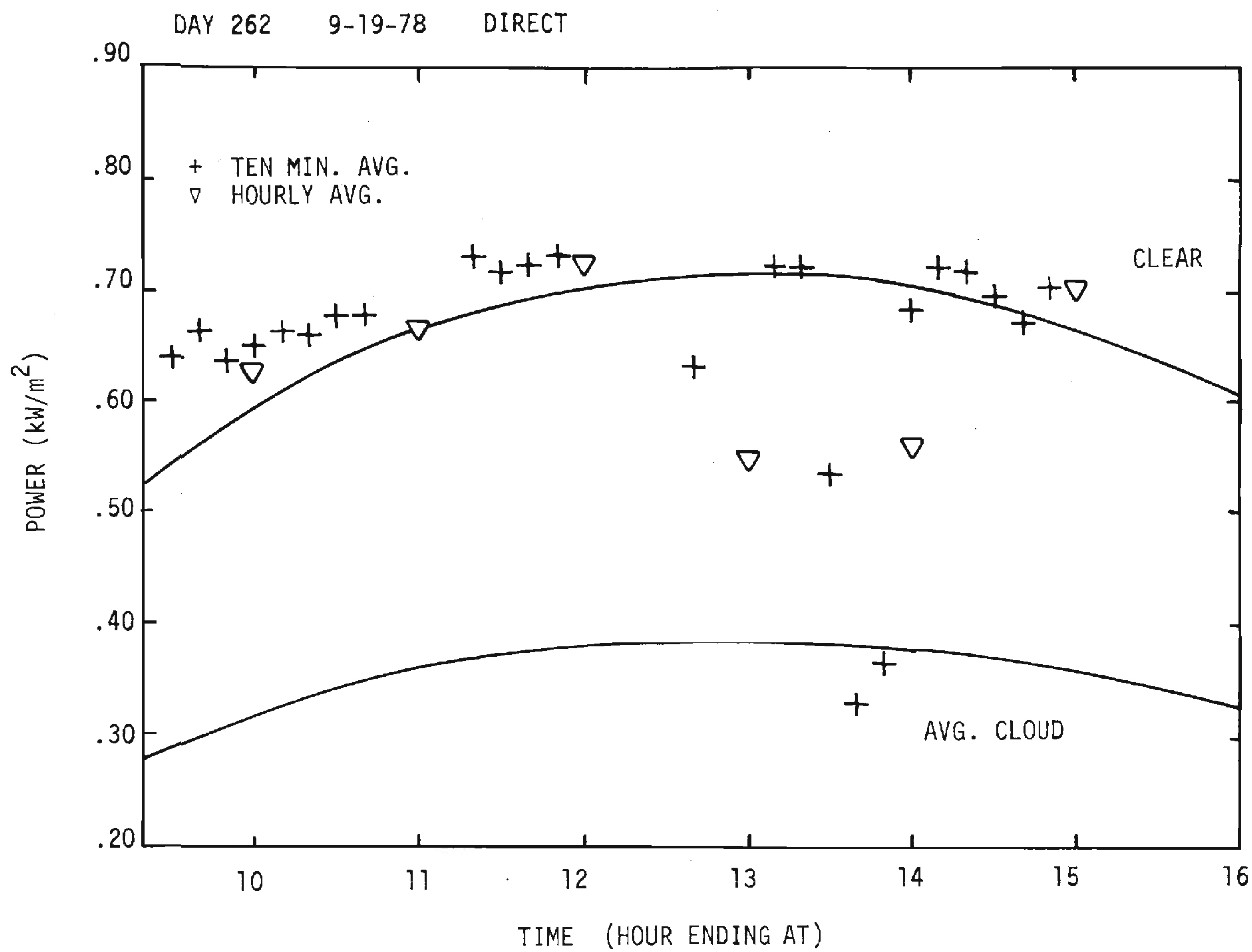


Figure 14. Observed and Modeled Direct Radiation 9/19/78

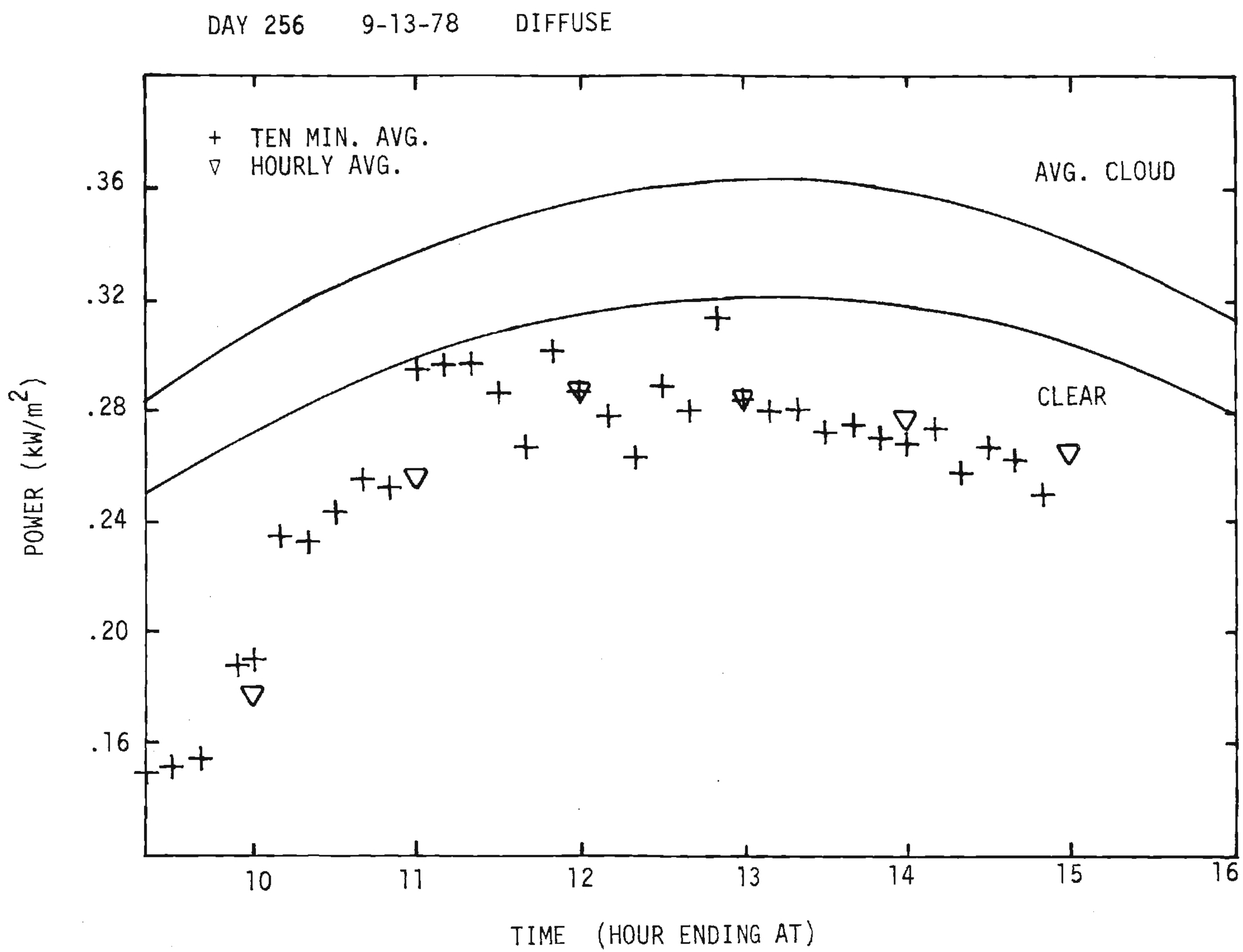


Figure 15. Observed and Modeled Diffuse Radiation 9/13/78

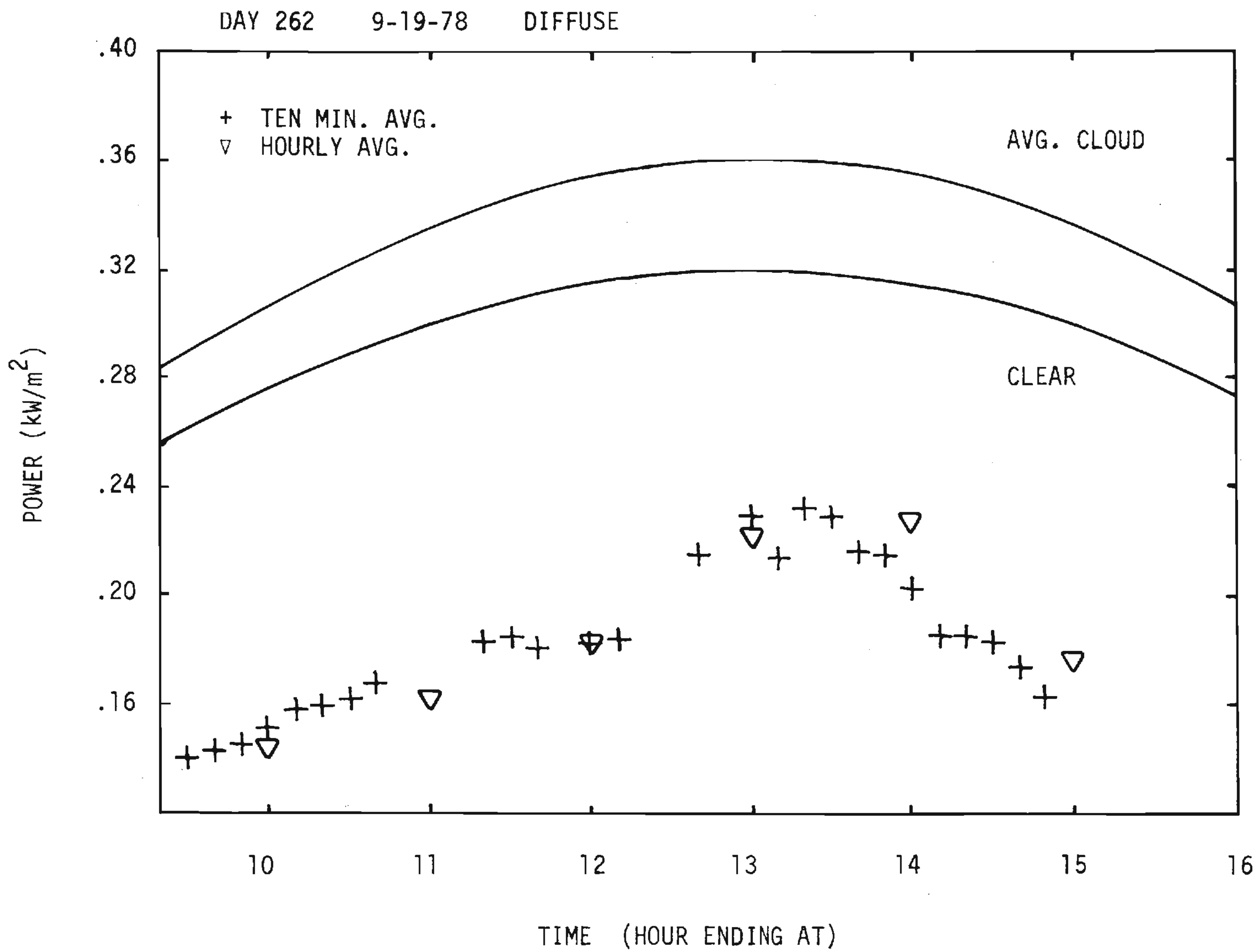


Figure 16. Observed and Modeled Diffuse Radiation 9/19/78

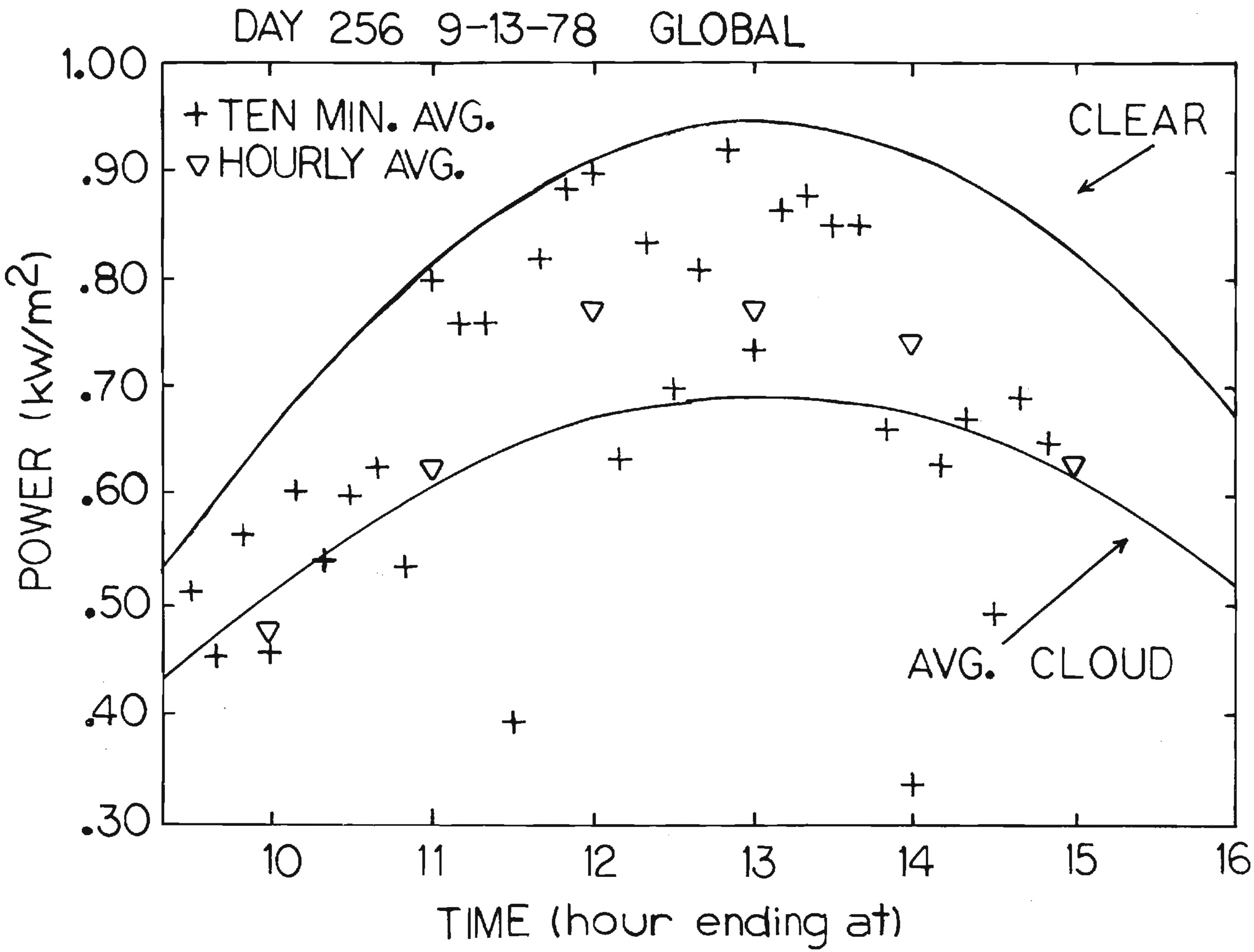


Figure 17. Observed and Modeled Global Radiation 9/13/78

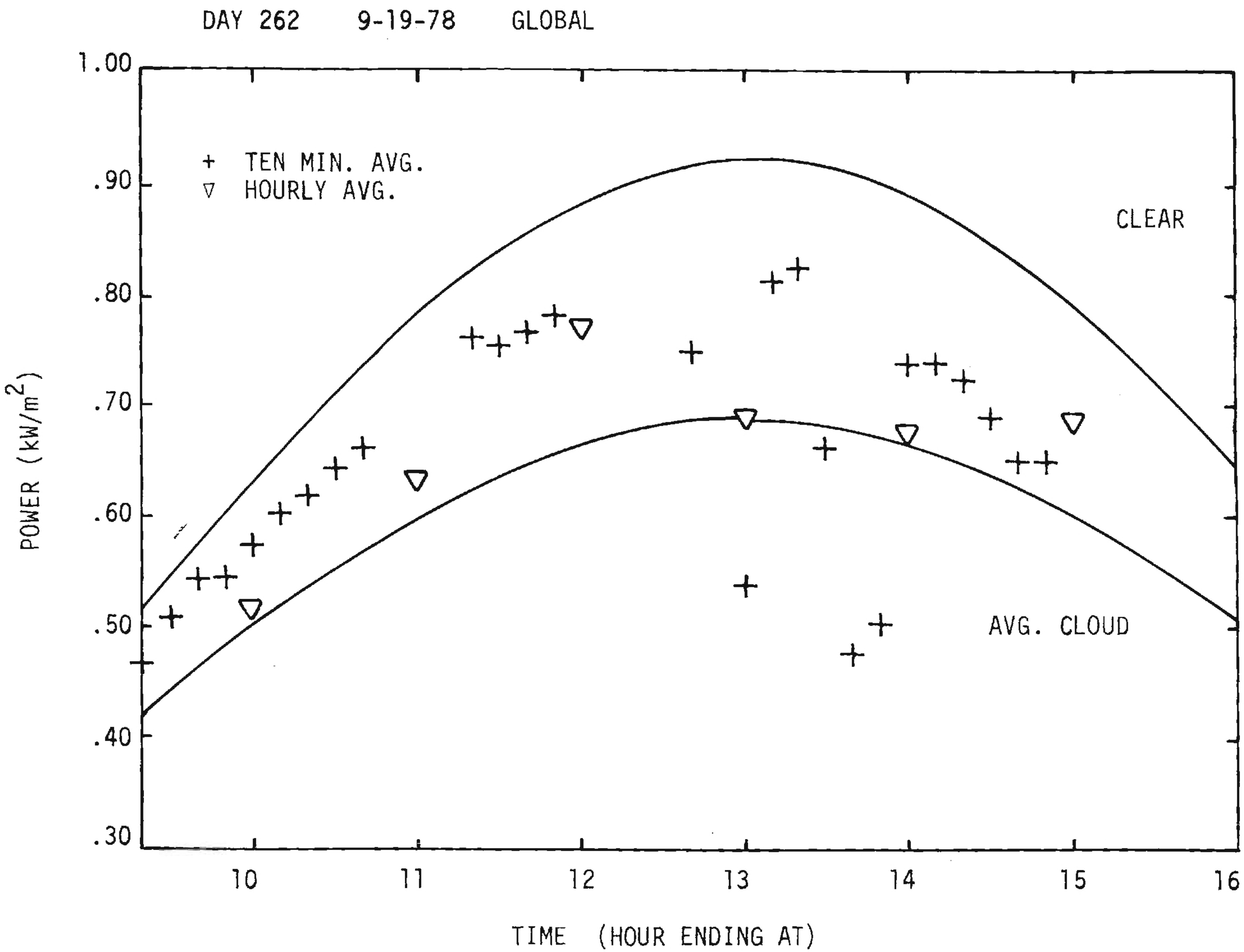
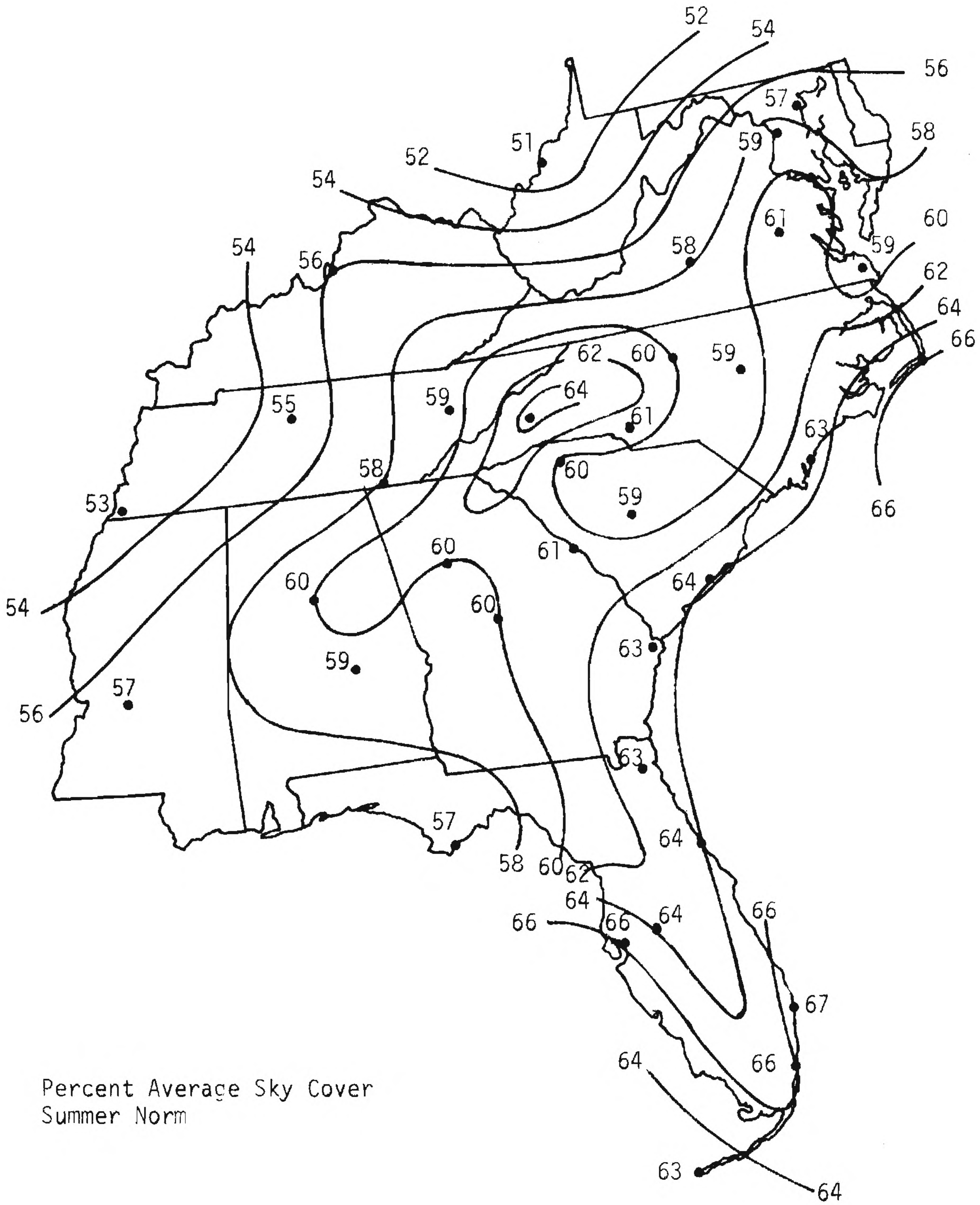


Figure 18. Observed and Modeled Global Radiation 9/19/78

7. REGIONAL SUNSHINE STATISTICS

Figures 19-22 show maps of the southeast region (Region 3) for summer and winter average sky cover and percent sunshine. Summer sky cover is highest and percent sunshine lowest along the Florida coast, and in the central Appalachians. Summer sky cover is lowest and percent sunshine highest along the Mississippi River. In winter highest cloud cover and lowest percent sunshine is near the Kentucky-West Virginia border. Lowest winter cloud cover and highest percent sunshine is in southwest Florida.

Other regional data activities by project personnel include generation and preparation of a 15 minute time scale 20 year solar radiation data base for Atlanta. From these data, a solar model year Atlanta data set (similar to the Typical Meteorological Year data set prepared by Sandia for other cities) has been created.



Percent Average Sky Cover
Summer Norm

Figure 19.

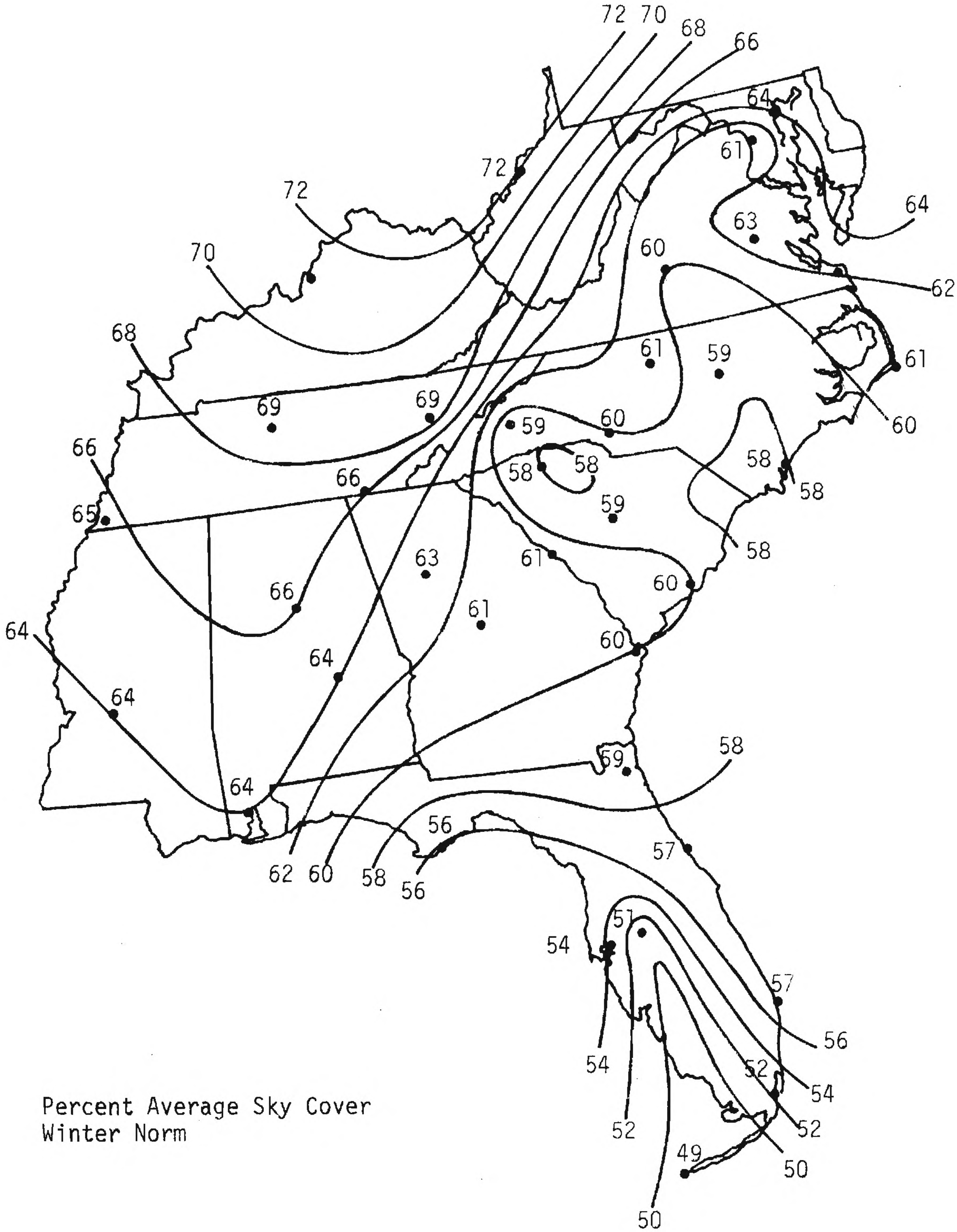
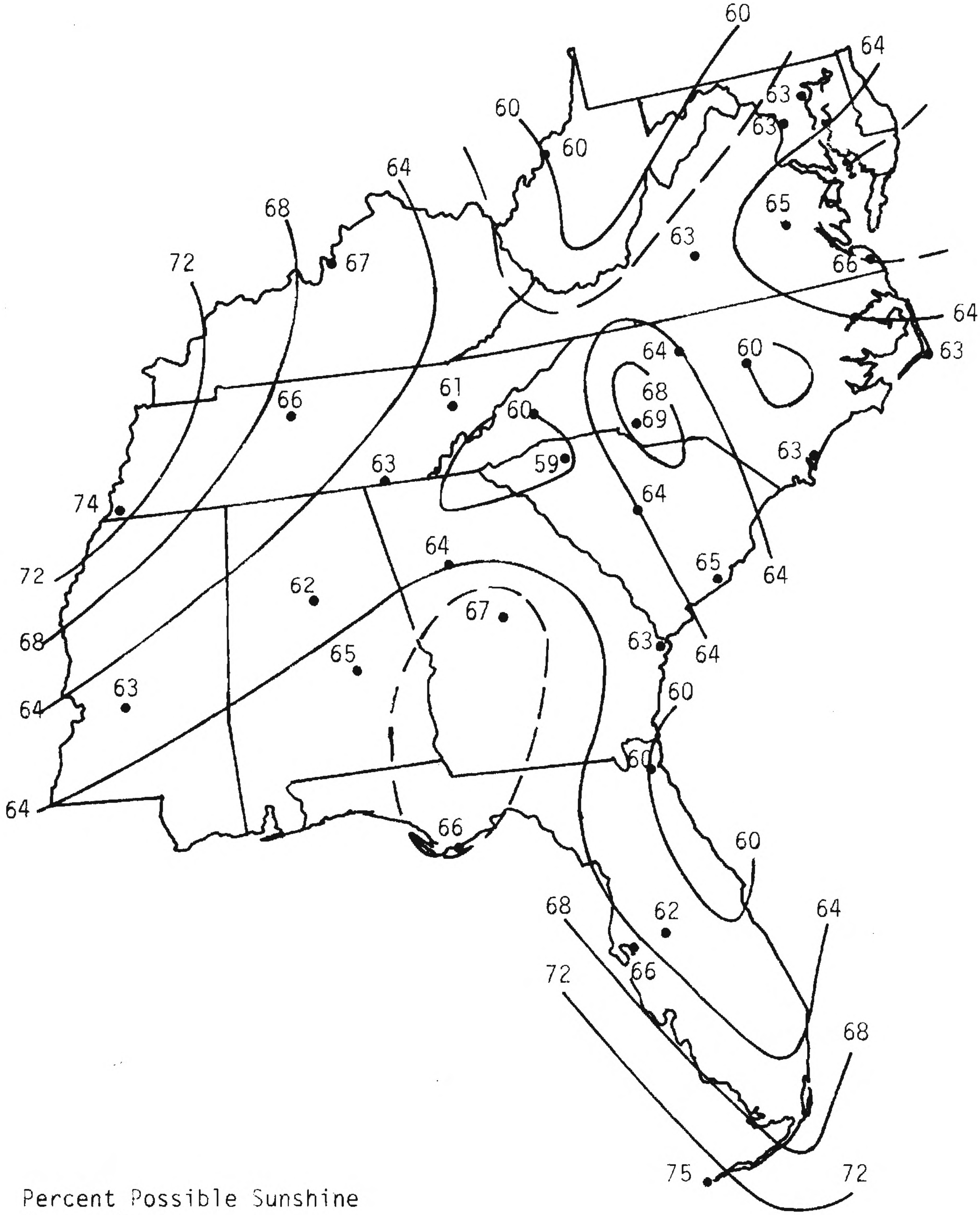
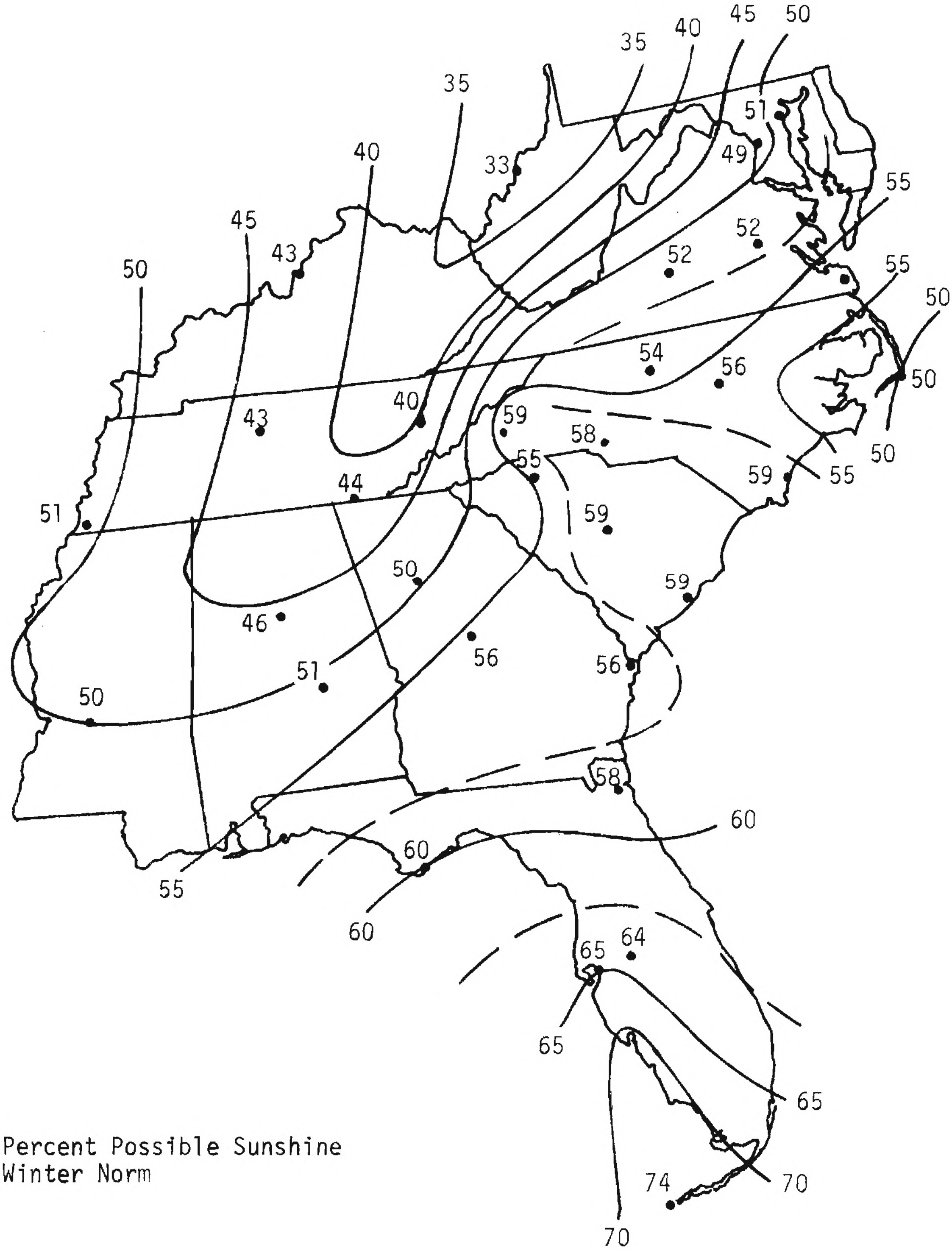

72 70
68
66
64
61
72
72
64
63
70
60
62
68
61
59
61
69
69
59
60
60
66
58
58
58
58
66
65
59
58
63
61
60
66
61
64
60
64
64
59
58
64
56
57
62 60
58
56
51
54
57
54
56
52
54
52
52
49
50
50
Percent Average Sky Cover
Winter Norm

Figure 20.



Percent Possible Sunshine
Summer Norm

Figure 21.



Percent Possible Sunshine
Winter Norm

Figure 22.

8. INSTRUMENT CALIBRATION TESTS AND INTERCOMPARISONS

After initial calibration and intercomparison tests the PSP #17064F3 and the NIP #17004E6 were selected as secondary standards for calibration transfer from the NOAA calibration laboratory. In addition a TMI active cavity radiometer (#67812) is used as a secondary standard for direct beam data and, via sun/shade readings as a calibration transfer to global instruments. Tables 4 and 5 show results of the final instrument intercomparison and calibration transfer from the secondary standard instruments after calibration at the NOAA calibration lab.

Table 6 gives a summary of the results of a National Active Cavity Radiometer Intercomparison conducted at DSET Labs in Phoenix, AZ, November 1-3, 1978. These results show that, on average, the Georgia Tech active cavity radiometer reads 0.39% lower than the reference NOAA active cavity radiometer. This can be corrected by adjusting the C_f factor up by 0.39% on the Georgia Tech instrument (TMI, private communication).

Table 4

PSP Calibration Results

Channel	Instr. Type	Serial No.	Factory Cal $\mu V/Wm^{-2}$	Sun/Shade Cal $\mu V/Wm^{-2}$ avg.	σ	σ%	Deviation from Factory Cal, %	Global Ref. to #38 $\mu V/Wm^{-2}$ avg.	σ%	Deviation from Factory Cal. %	Deviation from Sun/Shade %	Function
0	PSP	17061F3	9.79	9.67	0.12	1.3	-1.2	9.69	0.1	-1.0	0.2	Tilted
1	PSP	17059F3	9.67	9.45	0.05	0.5	-2.3	9.43	0.3	-2.5	-0.2	Spectral Shenandoah
2	PSP	17063F3	9.82	9.79	0.10	1.0	-0.3	9.85	0.3	0.3	0.6	Diffuse Spectral
3	PSP	17060F3	9.53	9.34	0.19	2.0	-2.0	9.42	0.1	-1.2	0.9	Global
4	SR75	77120	10.44	9.91	0.04	0.4	-5.1	9.88	0.3	-5.1	-0.3	SR75 Global
7	PSP	17062F3	9.73	9.64	0.03	0.3	-0.9	9.66	0.2	-0.7	0.2	Spectral
8	PSP	17351F3	9.70	--	--	--	--	9.79	0.2	0.9	--	Diffuse She- nandoah
13	PSP	17066F3	9.63	9.40	0.02	0.2	-2.4	9.55	0.3	-0.8	1.6	Tilted Shenandoah
14	PSP	15092F3	9.47	9.23	0.05	0.5	-2.5	9.38	0.2	-1.0	1.6	Spare
15	PSP	17064F3	9.57	9.50	0.12	1.3	-0.7	9.52	--	-0.5	0.2	Secondary Standard
16	PSP	17065F3	9.16	9.01	0.11	1.2	-1.6	9.12	0.2	-0.4	1.2	Diffuse

Table 5

NIP Calibration Results

Channel	Instr. Type	Serial No.	Factory Cal $\mu V/Wm^{-2}$	Direct Ref. to #28* avg.	Direct Ref. to #28* σ%	Deviation from Factory Cal %	Function
5	NIP	17004E6	8.52	8.52	0.4	0.0	Secondary Standard
6	NIP	17385E6	8.20	8.48	0.2	3.4	Spare
10	NIP	17008E6	6.64	6.78	0.2	2.1	Shenandoah Spectral
11	NIP	17003E6	6.76	6.84	0.2	1.2	Direct
12	NIP	16995E6	7.65	7.76	0.3	1.4	Spectral Direct

*AVG Ratio of ACR to #28 = 1.000 ± 0.003

Table 6

National Active Cavity Radiometer Intercomparison
Summary Results.

NOAA Reference in W/m^2. All other data expressed as ratio.

Run	NOAA Ref. 67502	NOAA 15745	Atmos. Env. Serv. 11399	Boeing 501	DSET 11402	DSET 14915	Ga. Tech 67812	JPL 66702	Sandia 67603	SERI 67814	Utah State 67707	
1	920.5	0.9973	0.9993	1.0018	0.9962	0.9986	0.9946	0.9966	0.9982	0.9974	0.9973	
2	935.7	0.9958	0.9983	1.0002	0.9967	0.9962	0.9935	--	0.9949	0.9945	0.9939	
3	930.3	0.9975	0.9980	1.0035	0.9973	0.9998	0.9975	0.9943	0.9990	0.9985	0.9988	
4	945.1	0.9947	0.9987	1.0020	1.0005	0.9964	0.9958	0.9934	0.9959	0.9968	0.9974	
5	915.7	0.9978	1.0014	--	1.0026	1.0005	0.9975	0.9979	0.9939	0.9994	0.9996	
6	897.3	0.9934	0.9999	1.0006	1.0006	0.9941	0.9941	0.9942	--	0.9958	0.9958	
7	853.6	0.9958	0.9971	1.0047	0.9957	0.9978	0.9961	0.9936	--	0.9979	0.9973	
8	912.4	0.9978	1.0001	1.0052	1.0002	1.0001	0.9985	--	0.9989	0.9994	0.9989	
9	924.1	0.9966	0.9981	1.0003	0.9978	0.9987	0.9959	0.9933	0.9982	0.9979	0.9964	
10	953.0	0.9975	1.0002	--	0.9970	0.9995	0.9970	0.9938	0.9979	0.9984	0.9981	
11	959.6	0.9965	0.9964	--	0.9976	0.9986	0.9957	0.9926	0.9987	0.9985	0.9977	
12	953.1	0.9965	0.9969	1.0022	0.9980	0.9998	0.9957	0.9934	0.9994	0.9987	0.9982	
13	929.6	0.9972	0.9992	1.0026	0.9989	0.9939	0.9974	0.9942	0.9987	0.9989	0.9987	
14	907.9	0.9966	1.0001	1.0030	1.0022	0.9983	0.9964	0.9925	0.9983	0.9971	0.9976	
15	882.1	0.9961	0.9956	--	0.9998	0.9909	0.9961	0.9939	0.9983	0.9972	0.9965	
AVG.	921.3	0.9965	0.9986	1.0024	0.9987	0.9975	0.9961	0.9941	0.9977	0.9978	0.9975	0.9977
σ	28.5	0.0012	0.0016	0.0017	0.0021	0.0028	0.0014	0.0015	0.0017	0.0013	0.0014	0.0021

9. TEACHING AND TRAINING ACTIVITIES

A short course on solar radiation measurements was planned for October to be offered immediately after a usually successful short course on solar heating and cooling. However, neither course received enough applicants to offer the course (the first time this has ever happened for the solar heating and cooling course). The course will be offered again in 1979 when it is hoped that more time for registration and advertising will gather a sufficient audience.

A graduate course Meteorology for Solar and Wind Energy is being offered in the Winter quarter under the School of Geophysical Sciences. This course is an elective course in the new Atmospheric Sciences Program at Georgia Tech and is open to all graduate students and to qualified seniors in various curricula.

Participation in the ISES International Conference in Atlanta in May 1979 and in a short course on solar energy at the Atlanta University Center, a nearby predominantly black college, are also planned activities for next year.

10. RESEARCH PLANS

Research activity plans for the coming year include:

1) construction of the first portable monitoring unit to measure several solar and meteorological parameters, to be put in the field some time late in the year at a yet-to-be-determined location. Parameters measured will include global, direct, diffuse, percent sunshine, global tilted, wind speed and direction, temperature, dewpoint, station pressure, and rainfall.

2) development of a continuously operating (daytime hours only) all-sky camera with time and date recording. Current plans call for a downward-looking weather enclosed time lapse camera, focused on a wide angle reflecting hemisphere, with a digital watch in the field of view for date and time.

3) development of automated sunshine duration recorder, using a NIP tracker with flip/flop amplifier averager. The flip/flop amplifier would output 0V if direct beam $\leq$ 200 W/m^2 and 10V if direct beam > 200 W/m^2. The averaged output of this circuit would read directly the percentage sunshine (0V = 0%; 10V = 100%). A device, similar to the Foster sunshine switch, using solar cells, will also be studied.

4) development of automated turbidity and precipitable water sensors. Three solar cells mounted in fixed tubes in an Eppley tracker, each tube with a fixed filter (500 nm, 880 nm, and 940 nm), constitute this device. From the 500 nm filter data, the turbidity can be inferred. From the combination of 880 and 940 nm, the precipitable water data are inferred. These devices would be essentially the same

as the Volz sunphotometer, except on an automatic tracker, with continuous readout on 3 separate channels. Airflow pumped through each solar cell tube will keep the interior from heating up due to the direct beam continuous tracking with each tube.